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Characteristics and potential impact of wastewaters from a coal-fired power plant at Colstrip, Montana.

CHARACTERISTICS AND POTENTIAL IMPACT OF WASTEWATERS FROM A COAL-FIRED POWER PLANT AT COLSTRIP, MONTANA

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CHARACTERISTICS AND POTENTIAL IMPACT OF WASTEWATERS FROM A COAL-FIRED POWER PLANT AT COLSTRIP, MONTANA

For

WATER QUALITY BUREAU
DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES
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INTRODUCTION

Colstrip 1 and 2 are two 360 megawatt coal-fired steam electric generating units located near the community of Colstrip, Montana about 30 miles south of the Yellowstone River in Rosebud County, Montana (Figure 1 and Plate I). These power plants utilize coal mined from the nearby Rosebud coal seam. The mine is owned and operated by the Western Energy Company, a subsidiary of the Montana Power Company, which controls large reserves of strippable coal near Colstrip and has been operating a strip mine there since 1968. Portions of this area were strip mined from 1924 to 1958 for use by the Northern Pacific Railroad Company. The Montana Power Company presently operates units 1 and 2, and has plans to construct two additional power plants of 700 megawatts each in the near future at this site.

The Colstrip power plants are adjacent to the East Fork of Armells Creek which flows northward approximately 16 miles where it joins another major tributary and forms Armells Creek. The East Fork of Armells Creek, in the vicinity of Colstrip, is a small intermittent stream that originates west of Colstrip. The dominant land use in the Colstrip area in past years has been for ranching and farming. There has been considerable concern for the possible environmental impacts of coal-fired power plants in Montana and these units are the first large units in Montana. In design of the generating facilities, the Montana Power Company chose a closed-loop water system to avoid any adverse impacts to natural water systems in the area. All liquid wastes from the Colstrip plant are impounded in ponds that are designed and constructed to minimize seepage losses. This expensive closed-loop system presently in use for Colstrip units 1 and 2 is the first fully contained water system for a coal-fired power plant in the Northern Great Plains.

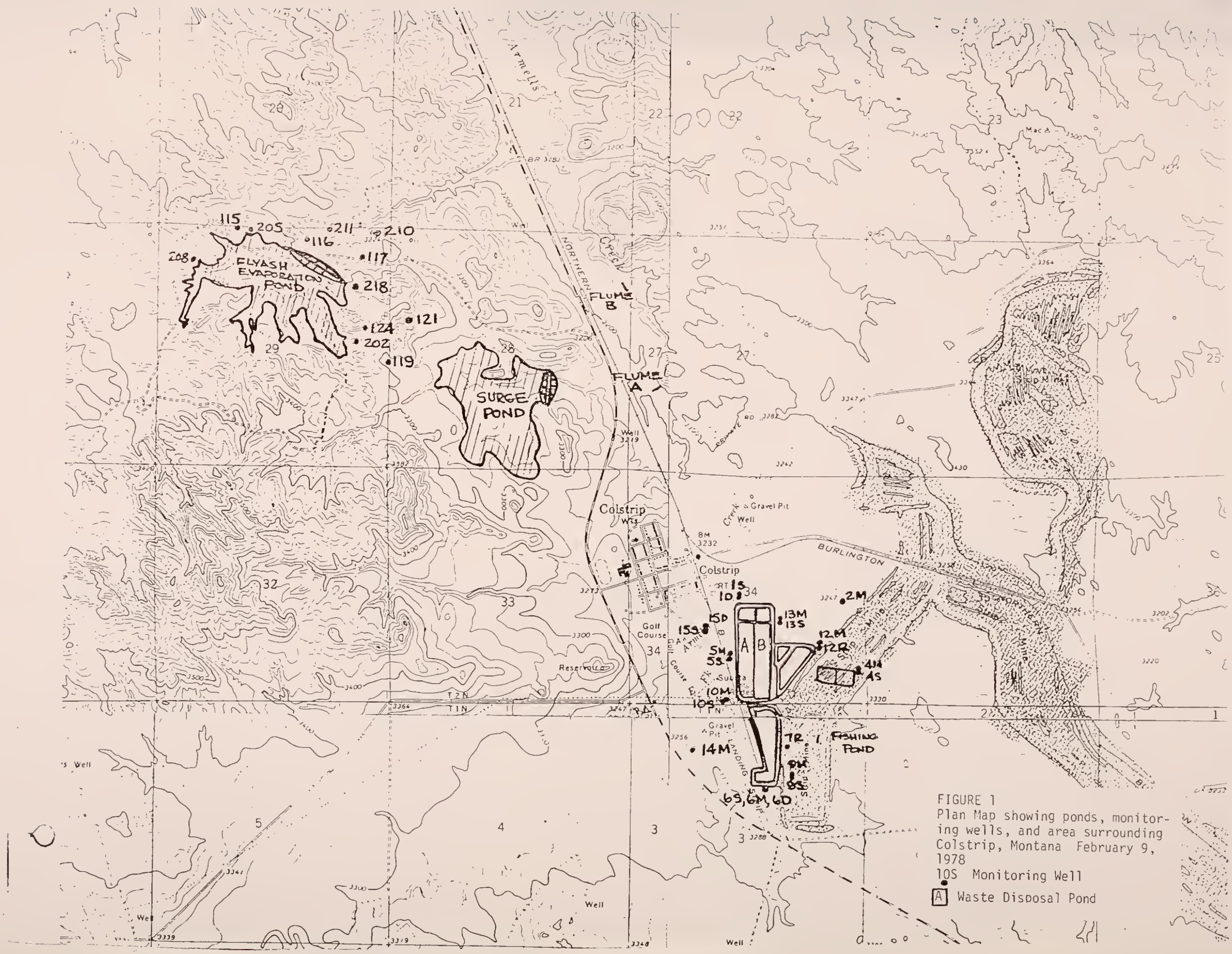


FIGURE 1
Plan Map showing ponds, monitoring wells, and area surrounding Colstrip, Montana February 9, 1978

10S Monitoring Well

[A] Waste Disposal Pond

The objective of this investigation was to determine the adequacy of pond containment and to determine the chemisty of effluents in the pond systems and assess impacts of the ponds on underlying groundwater systems. Another objective was to examine potential corrective measures that can be taken to minimize adverse impacts should significant amounts of pond seepage occur.

ACKNOWLEDGEMENTS

This investigation was funded in part by a grant from the Office of Energy Activities, EPA, Region VIII. The Montana Power Company provided monitoring wells, and a substantial share of the chemical data from these wells. Mr. Carlton Grimm, D.T. Berube, and Dick Myott, all of the Montana Power Company provided much technical information and assistance during the entire project and Gordon Hills, of the Montana Water Quality Bureau, provided assistance in water sampling. Mr. Van Thruston, of the Montana Fisheries Bioassay Laboratory conducted fish bioassays on waste waters and provided data on toxicity of the pond waters.

SUMMARY AND CONCLUSIONS

Colstrip Units 1 and 2 are two 360 megawatt coal-fired steam electric generating units using sealed ponds for disposal of liquid wastes, and closed-loop waste water systems to avoid discharges and impacts on natural waters in the area. A total of 22 wells were constructed to monitor groundwater underlying the waste disposal ponds near the power plant, and six monitoring wells were constructed near the flyash evaporation pond. There are two water-bearing zones beneath the plant ponds - the McKay coal seam and the McKay overburden. Aquifer tests show the McKay coal seam to have a low transmissibility averaging 238 gpd/ft., and the McKay overburden 757 gpd/ft.

Water level observations and chemical analyses of water from the monitor wells for the past 1½ years has shown the McKay coal seam aquifer to be unaffected by the plant ponds, however, the McKay overburden may be receiving an estimated 5 to a maximum of 15 gpm of seepage from the ponds near the plant. This is well within the anticipated seepage rate indicating the ponds are well sealed. Velocity of groundwater flow in the McKay aquifer in the plant pond area is estimated to be about .5 feet per day and, in the McKay overburden, about 1.5 feet per day.

Groundwater peripheral to the plant ponds and in the entire Colstrip area is poor in quality and some constituents including some major ions, trace elements, and nutrients, exceed some criteria for water supply, irrigation, and livestock uses.

The flyash evaporation pond has, as yet, received little wastewater; and, monitoring wells near this pond have shown no impacts in water-bearing zones underlying this pond.

Analysis of impacts of waste pond seepage shows that the only current impact is a probable decline in water quality of several wells in the McKay overburden near the plant ponds. Based on presently estimated pond seepage rates, long-term overall impacts of water seepage in the Colstrip area probably will not be measurable in streams, ponds, or groundwater except in the near vicinity of the ponds. If it is necessary to mitigate or eliminate seepage into aquifers peripheral to the pond, this can be accomplished by several techniques, the most suitable of which appears to be interception by a well system. Such a system could remove undesirable water from the aquifer and return this water back to the waste ponds.

The waste ponds were designed and constructed to minimize seepage loss and environmental impacts from waste waters. Based on this investigation, it is concluded that present waste water handling and containment technology provides excellent protection of water quality in hydrologic systems in the Colstrip area.

PONDS AND FACILITIES

Major components of the power plant and facilities water and wastewater systems are the water supply system, flyash and bottom ash disposal ponds, cooling tower blowdown ponds, brine disposal ponds, and the flyash evaporation pond. A schematic diagram showing the water supply and water disposal systems is shown in Figure 2, and a plan map of plant facilities is shown on Figure 1 and Plate I. Sanitary wastes from the plant are transported to the Colstrip community sewage treatment system.

Surge Pond

Water provided for Colstrip Units 1 and 2 originates from the Yellowstone River near Nichols, Montana and is transported via a 29-mile steel underground pipeline to the surge pond located near Colstrip (Figure 1). Water from the surge pond is pumped to the water treatment system, which consists of clarification, lime-softening, and chlorination. The majority of the treated water is then piped to the two plant cooling towers. Yellowstone River water from the surge pond also is used for municipal purposes by the community of Colstrip and for other water uses at the power plant. Boiler feedwater also is supplied from this system, but first passes through a demineralizer system to make the water suitable for high-pressure boilers.

Flyash Disposal Ponds

The wet scrubber system for Colstrip Units 1 and 2 consists of three venturi scrubber trains which utilize ponds A and B for disposal of particulates and the portion of the SO_2 removed by the scrubbers. Flyash is transported to two ponds and water used to slurry flyash from the plant is decanted from the ash material and recycled back to the scrubber system. Materials flow from the plant into flyash pond B then to flyash pond A, where decant water flows into the flyash clearwater pond.

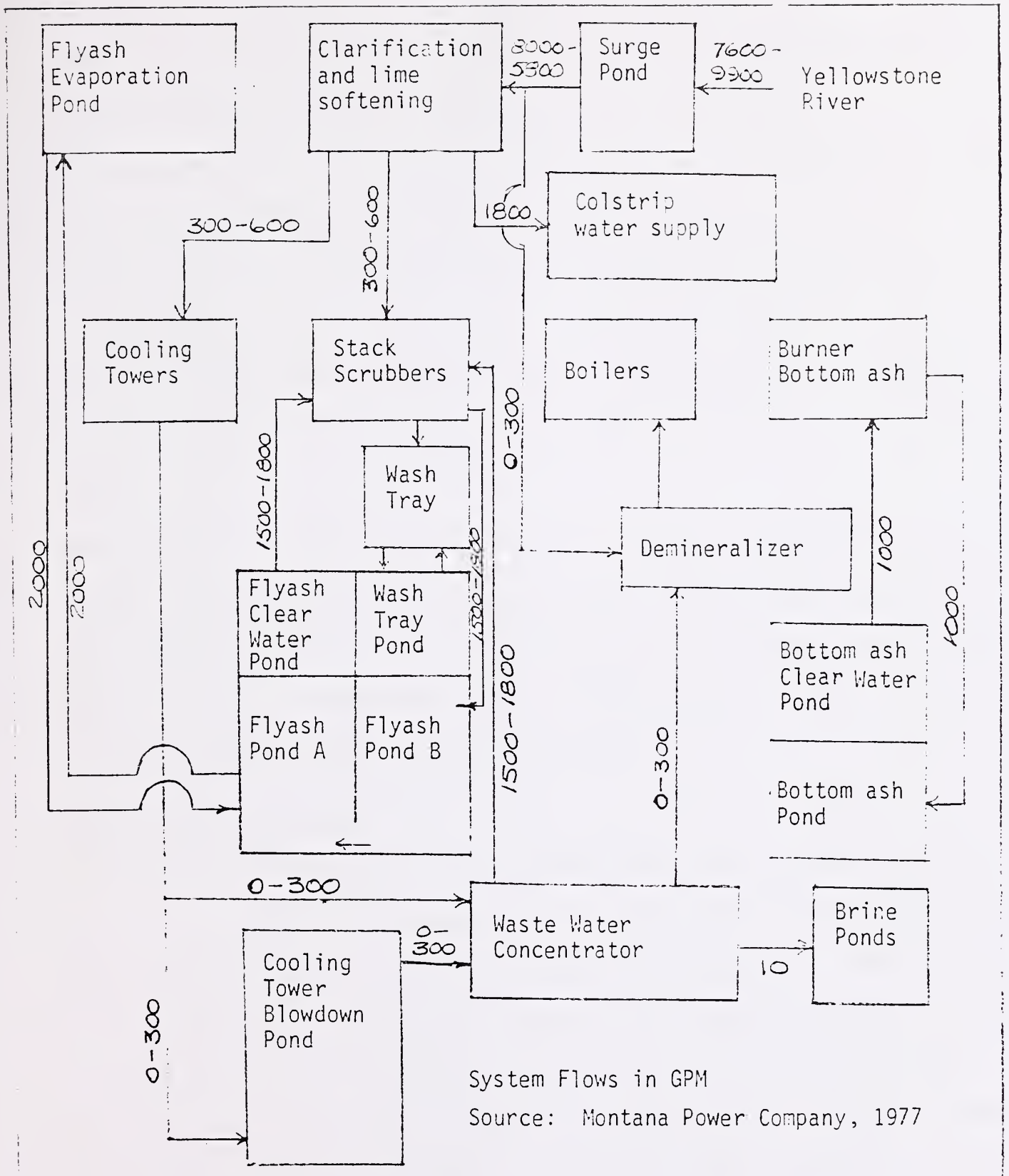


Figure 2. Schematic Diagram of Water Supply and Waste Disposal Systems at Colstrip Units 1 and 2, Colstrip, Montana.

Decant from the clearwater pond is returned to the air pollution contol system to transport flyash. Accumulated flyash in Ponds A and B is periodically dredged and put into a slurry pipeline and transported to the flyash evaporation pond site located northwest of Colstrip (Figure 1).

Sludge from the water softening process is added to flyash ponds A and B and increases pond pH. About 10 gpm is continuously removed from the softeners. Ponds A and B contain about 15.5 acres each (341 af volume). The flyash clearwater pond contains approximately three acres and 96 af volume.

Another part of the scrubber system is the three-acre washtray pond (58 af volume). This pond receives effluent from the scrubber washtrays, settled particulates, and recycles decant water back to the scrubber system. Solids deposited in the washtray pond are periodically removed by clamshell and are ultimately slurried to the flyash storage pond.

Bottom Ash Disposal Ponds

The bottom ash disposal pond receives bottom ash slurry from the two burner units. Decant from the bottom ash pond goes to a clearwater storage pond for recycle back to the plant to transport additional bottom ash. Make-up water to this bottom ash loop comes from demineralizer regeneration wastes and from various plant drains. The bottom ash pond has an area of about 4.8 acres (81 af volume). Sediment in this pond periodically is removed by clamshell to the flyash ponds and ultimately is slurried to final storage at the fly-ash evaporation pond.

Cooling Tower Blowdown Pond

Waste heat is removed by closed-loop induced draft cooling towers. To prevent scaling, controlled concentration of dissolved materials in the cooling tower circuit is maintained by removal of a portion of the water

that enters the circuit. This wastewater termed "blowdown", goes to the 17-acre (408 af volume) cooling tower blowdown pond (Plate I). To avoid a substantial buildup in dissolved solids in the cooling tower blowdown pond , the water from this pond is fed at a relatively constant rate of about 300 gpm to a wastewater concentrator where it is separated into a concentrated brine and fresh water. The concentrated brine (about 10 gpm) flows to brine storage ponds, while the fresh-water product goes back to the scrubber system. There is very little sediment deposited in the blowdown pond.

Brine Disposal Pond

The two brine disposal ponds are each about 1.7 acres in size and are used to receive, contain, and store brine from the wastewater concentrator. Brine will accumulate in the ponds without removal or disposal. The material in the ponds, upon completion of pond life, will essentially be a solid and the intent is to review the then current methodology and determine the best reclamation practices and then reclaim these ponds (Montana Power Company, 1977).

Flyash Evaporation Pond

The 168-acre flyash evaporation pond located about 2 miles northwest of Colstrip receives flyash wastes from the flyash pond via a slurry pipeline. This pond provides separation of water from the slurried ash material, and return of decanted water via the same pipeline to the power plant area. This pond ultimately will be filled with ash and will be reclaimed. An estimated 200,000 to 270,000 tons of flyash are removed from the flyash ponds annually by a small dredge that operates 30 to 40 percent of the time - an equivalent of 4 to 5 months per year (Montana Power Company, 1978, Carlton Grimm, pers. comm.). The flyash pond is designed to store a total of 2360 acre-feet of ash. (Bechtel, 1975 p.4).

POND DESIGN AND CONSTRUCTION

The design decision to use a closed-loop waste system has created a need for ponds and an emphasis on complete containment to minimize seepage. Excessive seepage would defeat the objective of total containment and could create environmental problems. In pond design and construction; seepage from dikes and bottoms was kept low by compaction and use of liners where needed.

Surge Pond

Principal considerations in location of the 112-acre surge pond were that it be suitable for containment of the required volume of water; minimal disturbance of the terrestrial ecology and existing land use; the pond must be in an area where seepage losses are potentially low; cost of the installation low, and recreational potential of the area high (Westinghouse, 1973). Of the five sites considered, a site located in a broad valley approximately 1.3 miles northwest of the steam plant was chosen. Based on hydraulic tests, the expected seepage from this pond was 112 gpm.

After construction, the surge pond was found to have significant leakage in a dam abutment. This leakage entered the groundwater system downstream from the dam and subsequently entered the East Fork of Armells Creek. Water in the surge pond is substantially better in quality than water in the Armells Creek system, and resulted in an improvement in the quality of water in the stream. A grouting program at the dam abutment has stopped this leakage.

Water in the surge pond is from the Yellowstone River, thus, seepage losses did not pose a threat to surface or groundwater quality. Such water losses, however, were expensive, and minimum seepage losses were desirable.

Flyash Evaporation Pond

The flyash evaporation pond had selection criteria which included a relatively impermeable subsurface material; potential for being reclaimed after use of the area is completed, and the ability to contain a long-term supply of flyash which would accumulate from normal power plant operation. The area selected is approximately two miles northwest of the town of Colstrip. The pond is designed for a storage of ten years of flyash from Colstrip units 1 and 2, plus a flood storage reserve. Total capacity of the pond is approximately 2,855 acre feet (Bechtel, 1975). The pond is located in a dissected stream valley draining into the East Fork of Armells Creek, (Figure 1). The pond is underlain by shale, siltstone, sandstone, and two coal seams of the Tongue River Member of the Fort Union Formation. Permeability tests were made on representative undisturbed foundation soil samples and on remolded samples from borrow areas (Bechtel, 1975). The dam is designed with an impervious core and a foundation cut-off trench. An embankment drain system including a chimney drain, incline drain, and horizontal blanket drain on the downstream side of the embankment was installed to minimize piping failures and to collect the seepage and return the seepage to the pond. Field permeability tests were performed on 61 intervals, in 15 drill holes at the evaporation pond site (Bechtel, 1975). Seepage from the pond is predicted to be 79 gpm (Bechtel, 1975). Interception of seepage beneath the dam will control a major portion of this and a net total seepage of 13 gpm is anticipated for the dam.

Portions of the dam site had permeable material exposed including fractured and broken rocks. These materials were blanketed with impervious materials to minimize seepage.

Ponds at Plant Site

The waste water ponds near the power plant were designed to have minimum seepage and considerable effort was taken to insure a design of both dike and pond bottoms that result in a relatively impermeable barrier and would adequately contain the waste waters. Both the flyash and blowdown ponds were lined with the locally derived silty clay material which had a permeability of approximately one foot per year, and actual laboratory tests of permeability indicated .01 to .05 feet per year. The flyash pond is underlain by about 25 feet of siltstone which in turn is underlain by the McKay coal. Old shallow channels in the bottom of the flyash pond were removed and this material was replaced with a compacted silty clay. In the flyash pond, a silty clay lining was applied to the sides of the ponds and the natural siltstone was compacted and left in place in the bottom (Bechtel, 1976). Based on the laboratory testing of materials used on the dikes and the material present on the pond bottoms, estimated seepage from the ponds in the vicinity of the power plants is:

Pond	Seepage (gpm)
Flyash Ponds (all 4 ponds) (Pond A, Pond B, Clearwater & Washtray ponds)	13
Cooling Tower Blowdown Pond	15
Bottom Ash Ponds (2 ponds)	8
Brine Waste Ponds	0

Source: Bechtel, 1976

Specifications for ponds near the plant (Bechtel, 1974) show the bottom ash pond, bottom ash clearwater pond, flyash clearwater pond, and washtray pond are all underlain by compacted soil overlain by a clay blanket having a three-foot minimum thickness. All dikes around these ponds also are lined by a three-foot clay blanket. The flyash ponds A and B and the blowdown pond are underlain by compacted native silt-clay soil. Dikes on these ponds contain a clay core having a minimum thickness of 20 feet. Any coal seams present in the ponds were covered by a three-foot minimum clay blanket.

Brine Disposal Ponds

The brine disposal ponds D-1 and D-2 had hypalon membrane liners installed in November, 1975. The material is a two-ply construction with two 15 mil thicknesses of black hypalon sheeting laminated to one thickness of one-ply nylon reinforcing fabric for a final thickness of 30 mils. Preparation of the site involved compaction of the sides and bottoms of the basin and placement of three to four inches of sand on the pond bottom.

Hypalon has an excellent breaking strength, tear strength, and is ozone resistant. It has a good resistance to bending failure in cold weather. According to the Montana Power Company (1977),

> Each pond has the capacity to hold 592,416 cubic feet of brine. Presently, as of March, 1977, brine pond D-1 contains 211,046 cubic feet of brine, while pond D-2 is empty. The brine in storage now represents 18 percent of the total storage capacity of both ponds.

As further described by the Montana Power Company,

> The manufacturer estimates that the actual life of the liner is at least 40 years. This figure is based on normal use of the ponds which includes emptying and refilling the ponds periodically.

The plan for use of these ponds is to allow the solids to accumulate in the ponds without removal or subsequent disposal. Thus, without the normal removal and disposal activity, life of the liner should be substantially extended.

Hypalon is widely used to contain a variety of toxic wastes and is an excellent membrane liner. There should be no seepage from these ponds.

GEOLOGY

The entire area is underlain by the Tongue River Member of the Fort Union Formation of Tertiary geological age. The Rosebud coal seam, which is the object of past and current coal mining in the area, outcrops along the south and east edge of the pond area (Figure 1), and was encountered in monitoring wells 7R and 12R. Just east of these holes, the Rosebud coal seam has been mined and spoils are present (Plate 1). As described by Van Voast, Hedges, and McDermott (1977):

> The Rosebud and McKay coal beds have thicknesses of about 25 feet and 10 feet, respectively, and they are separated by clay, silt, and sandbeds of extremely local thickness. Total thickness of materials, here termed Rosebud-McKay "interburden", ranges between about 3 and 60 feet. The interburden thickness is not predictable at any location, and has no apparent areal trend. . .

The interburden thickness is about 25 feet in the power plant pond area. The Rosebud seam was mined to near its outcrop and is present only along the extreme northern and eastern edge of the pond area. No precise location of this edge was possible from the drilling data. The Rosebud coal is absent over most of the pond area, therefore, strata above the McKay coal are termed McKay overburden in this report. Based on limited data, an attempt was made to draw a structural contour map on the top of the McKay coal seam. The spacing of test holes, however, was too great to determine the shape of this surface. The test hole data does, however, show a structural high on the south end of the pond and a low in the flyash - bottom ash pond area (Appendix II). In the vicinity of the plant ponds, materials encountered in drill holes primarily were silt, silty sand, siltstone clay, with some scattered fine-grained sandstone and coal. Geological logs of all exploration wells are in Appendix II. In well 4M, and 4S, 32 and 35 feet, respectively, of mine spoils were present in the old coal mining area and at holes 9S and 9M, 72 feet of mine spoils were

present. Along the east edge of the ponds, some baked shale particles are present in the overburden and east and south of the ponds (near 14M), a large clinker deposit was present (Rosebud burn material), but much of this material has been removed for construction purposes.

Along, and parallel to the East Fork of Armells Creek, there is a relatively narrow deposit of unconsolidated alluvium consisting of beds of silt and clay, overlying beds of sand and gravel with a total thickness as great as 40 feet. This alluvium was not mapped as part of this project, but is an estimated 500 to 900 feet from the ponds.

The flyash evaporation pond area is underlain by fine-grained sandstones, scattered thin coal lenses and shale. The south portion of the flyash evaporation pond area contains thick layers of clinker consisting of baked and fractured shales and sandstones. A relatively thick coal layer was encountered in test holes 121, 102, 119, and 218. Geology of the area is variable and lithologic correlation from hole to hole is difficult. This flyash evaporation pond reflects the typical variability of the Tongue River Member of the Fort Union Formation. Geologic logs of all test holes in the flyash evaporation pond area are shown in Appendix II.

HYDROLOGY

General surface and groundwater hydrology of the Colstrip area has been described by Van Voast, Hedges, and McDermott (1977). Bedrock in the Colstrip area is the Tongue River Member of the Fort Union Formation. The two major aquifers are the Rosebud and McKay coal seams with the Rosebud the objective of past and present coal mining activity. The Rosebud and McKay coal beds are separated by an interburden that, according to Van Voast, Hedges, and McDermott (1977), ranges in thickness between 3 and 60 feet and is not predictable in thickness at any location and has no apparent areal trend. Along the East Fork of Armells Creek, unconsolidated alluvium as much as 30 feet thick consisting of layers of silt, clay, sand and gravel, overlies bedrock.

In the Colstrip area, recharge to the groundwater system is from infiltration of precipitation in bedrock outcrops, colluvium, alluvium, and seepage from ponds and streams in the area. Discharge of groundwater is to streams, through wells and springs, and into mine workings. The balance between recharge and discharge in the groundwater system causes fluctuations in water levels which represent temporary gains and losses of stored water. The hydrologic balance in the Colstrip area has not been examined in detail and specific relationships of precipitation to groundwater and surface waters are not well known.

Of particular concern in this investigation were groundwater levels peripheral to the waste disposal ponds; direction and rate of movement of groundwater from these ponds, and changes in quality of water in aquifers beneath the ponds. To obtain this information, monitoring wells were drilled to determine changes in water levels, aquifer hydraulic characteristics, and groundwater quality. The direction and rate of

water movement can be assessed by determination of gradients on the water table or piezometric surfaces in aquifers beneath the ponds.

Monitoring Well Construction

A total of 22 monitoring wells were constructed to monitor the groundwater underlying the pond areas near the plant to determine if there is movement of fluid from these ponds into the underlying groundwater system. Similarly, six monitoring wells were constructed near the flyash evaporation pond. Location of the test wells are shown in Figure 1; a summary of well data in Table 2, and logs in Appendix II. The general technique of well construction near the plant ponds was drilling with an eight-inch helical auger to the desired depth and casing of the holes with four-inch PVC plastic pipe, slotted with narrow saw-cut slotsin the water-bearing interval. The PVC pipe was gravel-packed in the water-bearing interval, a bentonite seal placed over the gravel pack, and the annulus between the drilled hole and the pipe was filled with cement to the ground surface. At the ground surface, a steel pipe was extended above the ground one to two feet to protect the four-inch plastic pipe. Test holes near the flyash evaporation pond were drilled with an NX (2 15/16 inch) rotary drill; reamed to six inches and a four-inch PVC pipe inserted in the hole. The holes were then gravel packed; a bentonite seal applied, and a clay backfill or cement grout placed to the ground surface and a steel protective casing installed. After completion of the test holes, all holes were flushed by the contractor using Yellowstone River water to remove debris from the hole, and to clean up silt and sand that washed into the hole and the gravel pack.

TABLE 2 Monitoring Well Data
Summary for the Colstrip Pond Area

Well Designation	Location	Altitude (ft) MSL Ground / Top of Casing	Date Completed	Total Well Depth	Casing Diameter (in)	Depth of Water (ft. below top of well Casing)	Date Meas.	Internal Perforated (ft)	Aquifer
1S	2N 41E 34CAA	3238.2 / 3239.7	5/13/76	35.0	4.0	16.0	8/25/76	23.0 - 33.0	McKay Overburde
1O	2N 41E 34CAA	3238.1 / 3240.0	5/13/76	60.0	4.0	15.3	8/25/76	48.5 - 58.5	McKay Overburde
2M	2N 41E 34DAA	3260.98 / 3262.5	5/11/76	52.5	4.0	25.0	8/25/76	41.0 - 51.0	McKay Coal
4M	2N 41E 34DOA	3275.6 / 3277.0	5/15/76	77.6	4.0	38.4	8/25/76	66.1 - 76.1	McKay Coal
4S	2N 41E 3400A	3275.7 / 3277.0	5/15/76	40.0	4.0	39.9	8/25/76	28.0 - 38.0	McKay Overburde
5M	2N 41E 34CAD	3243.8 / 3245.3	5/6/76	47.6	4.0	11.5	8/25/76	36.1 - 46.1	McKay Coal
5S	2N 41E 34COA	3243.7 / 3245.2	5/6/76	31.0	4.0	11.9	8/25/76	19.0 - 29.0	McKay Overburde
6O	1N 41E 03ACB	3277.8 / 3279.6	5/7/76	99.0	4.0	39.4	8/25/76	84.0 - 94.0	Sub McKay
6M	1N 41E 03ACB	3277.3 / 3279.2	5/8/76	45.0	4.0	35.0	8/25/76	33.5 - 43.5	McKay Coal
6S	1N 41E 03ACB	3277.2 / 3279.0	5/9/76	27.5	4.0	DRY	8/25/76	14.0 - 24.0	McKay Overburde
7R	1N 41E 03ABO	3265.4 / 3267.0	5/13/76	37.8	4.0	32.26	8/25/76	26.3 - 36.3	Rosebud Coal

9M	1N 41E 03ACA	3286.6 / 3288.1	5/9/76	60.0	4.0	53.4	8/25/76	46.5 - 56.5	McKay Coal
9S	1N 41E 03ACA	3286.8 / 3288.6	5/11/76	40.0	4.0	ORY	8/25/76	28.0 - 38.0	McKay Overbu
10M	2N 41E 34CDO	3255.99 / 3257.3	4/30/76	53.0	4.0	23.5	8/25/76	38.5 - 48.5	McKay Coal
10S	2N 41E 34COO	3255.7 / 3257.5	4/30/76	38.0	4.0	23.8	8/25/76	26.0 - 36.0	McKay Overbu
12M	2N 41E 34OAC	3278.0 / 3280.4	5/12/76	75.0	4.0	38.0	8/25/76	60.0 - 70.0	McKay Coal
12R	2N 41E 34OAC	3278.5 / 3280.2	5/7/76	42.5	4.0	40.5	8/25/76	24.5 - 34.5	Rosebud Coal
13M	2N 41E 34OBC	3244.1 / 3245.6	5/10/76	37.5	4.0	7.6	8/25/76	25.3 - 35.3	McKay Coal
13S	2N 41E 34OBC	3244.3 / 3245.8	5/11/76	24.0	4.0	5.45	8/25/76	17.5 - 22.5	McKay Overbu
14M	1N 41E 03BBO	3256.1 / 3257.8	5/3/76	34.7	4.0	22.0	8/25/76	22.5 - 32.5	McKay Coal
15D	2N 41E 34CAC	3232.1 / 3234.2	5/16/76	60.0	4.0	6.2	8/25/76	42.0 - 52.0	McKay Overbur
15S	2N 41E 34CAC	3232.2 / 3233.6	5/17/76	40.0	4.0	6.6	8/25/76	28.0 - 38.0	McKay Overbur
115	2N 41E 29BABA	3321 /	4/21/75	30.0	1½			15-25	Sandstone Interburden?
116	2N 41E 29ABAB	3290 /	4/21/75	25.0	1½			10-20	Sandstone Interburden?
117	2N 41E 29AABO	3255 /	4/21/75	25.0	1½			10-20	Sandstone Interburden?

119	2N 41E 29OAAD	3296 / 3299.2	4/23/75	1DO.0	4.0	45.2	12/18/75	70.0 - 95.D	Sandstone & Shale below McKay
121	2N 41E 28BCB	3315 / 3317.5	4/25/75	95.1	4.D	63.3	12/2D/75	58.D - 93.D	SS above McKay McKay Coal SS below McKay
124	2N 41E 29ADDB	3365 /	4/25/75	96.0	1½			BD-9D	Sandstone Interburden
202	2N 41E 29ADCD	3317.7 /	9/23/75	99.9	2.0	61.D	9/23/75	61.6 - 94.6	SS above McKay McKay Coal SS below McKay
205	2N 41E 29BAAB	3304.2 / 3306.3	10/29/75	100.7	4.D	DRY	10/29/75	65.0 - 75.0	Siltstone, SS below McKay
								B5.D - 95.D	McKay absent
208	2N 41E 29BBDB	3314.9 / 3317.7	11/9/75	96.5	4.0	69.B	12/23/75	60.0 - 95.D	SS, Siltstone below McKay
210	2N 41E 29AAAB	3248.55 / 3251.7	12/15/75	9B.D	4.0	47.2	12/20/75	60.0 - 94.0	SS, Siltstone below McKay
211	2N 41E 29ABAA	3252.5 / 3255.5	12/3/75	99.4	4.D	44.3	12/9/75	5B.D - BB.D	SS, Claystone below McKay
218	2N 41E 29AACD	3352.4 /	11/17/75	137.6	1½	1D3.7	11/17/75	92.4 - 127.4	SS above McKay McKay Coal SS below McKay

SOURCE: Bechtel, 1976, Groundwater Monitoring Program Colstrip Power Plant Units I & II
Montana Power Company

During sampling it was noted that several holes were turbid and could not be "cleaned up" by pumping. These holes were redeveloped using an air compressor which vigorously surged the wells and reduced or eliminated the turbidity problem.

Aquifer Characteristics

Aquifers in the vicinity of waste ponds at Colstrip were tested by pumping the monitoring wells at a constant rate and observing drawdown in the pumped well. A total of 16 short duration tests and nine intermediate duration tests were conducted. Results of these tests (Table 1) provided data for calculation of transmissibility for the strata utilizing the Jacobs modification of the Theis nonequilibrium equation (Todd, 1959).

A series of short duration tests were conducted to determine approximate aquifer characteristics and, in selected wells, longer duration tests were run to more accurately determine transmissibilities. For the short duration tests, transmissibilities were estimated from specific capacity based on the Theis nonequilibrium equation (Todd, 1959). The short duration tests generally give a good indication of the aquifer transmissibilities and were useful for selection of representative wells for longer duration tests.

Where transmissibilities are determined for the longer duration tests, these transmissibilities are assumed to be more accurate than those of the short duration tests. Wells 13-S and 13-M were not tested. During redevelopment of these wells, it was apparent that their yields were very small and transmissibilities of these two wells were estimated to be less than 75 gpd/ft. Transmissibility of wells completed in the McKay coal aquifer ranged from 78 to 556 gpd/ft. and averaged 238 gpd/ft., and wells in the overburden ranged from 230 to 2580 gpd/ft., and averaged 757 gpd/ft.

Aquifer test results showed the McKay coal seam to be a relatively poor aquifer with more uniform and lower transmissibilities than the McKay overburden. The range of transmissibility values measured are similar to those reported by Van Voast, Hedges, and McDermott (1977) for the same units in the Colstrip area.

Storage coefficients for water table aquifers are approximately equivalent to effective porosities, and generally range between .05 and .25. In confined or semi-confined aquifers, storage coefficients are substantially less and commonly range between .01 and .00001. Van Voast, Hedges and McDermott (1977) indicated storage coefficients in the sandstone and coal beds were approximately .00001. This indicates these materials are confined. Storage coefficients in wells peripheral to the ponds were not measured, but probably have values similar to those previously measured in confined aquifers in the Colstrip area.

TABLE 1
SUMMARY OF TESTS OF TRANSMISSIBILITY FOR AQUIFERS
IN THE VICINITY OF WASTE DISPOSAL PONDS AT COLSTRIP, MONTANA

Test Hole	Date Tested	Location	Aquifer	Well Yield (gpm)	Test Duration (Minutes)	Draw Down (Feet)	Transmissibili+ gpd/ft.
1S	2/9/77	2N41E34CAA	McKay Over-burden	3.2	12	0.69	7100
1S	10/4/77	2N41E34CAA	McKay Over-burden	17.6	285	4.97	2581
1D	2/9/77	2N41E34CAA	McKay Over-burden	3.2	15	7.92	400
1D	10/5/77	2N41E34CAA	McKay Over-burden	7.14	235	27.94	258
2M	8/25/77	2N41E34DAA	McKay Coal	1.10	220	7.87	239
4M	2/8/77	2N41E34DDA	McKay Coal	3.2	10	28.0	130
5S	2/8/77	2N41E34CDA	McKay Over-burden	4.4	15	9.50	570
5M	2/8/77	2N41E34CAD	McKay Coal	2.5	15	15.66	190
5M	8/25/77	2N41E34CAD	McKay Coal	1.65	220	12.60	202
6M	8/25/77	1N41E03ACB	McKay Coal	0.53	40	7.66	78
6D	2/8/77	1N41E03ACB	Sub McKay	5.5	15	10.35	700
6D	10/4/77	1N41E03ACB	Sub McKay	6.4	235	16.92	331
10S	2/8/77	2N41E34CDD	McKay Over-burden	2.3	15	1.77	1800
10S	9/29/77	2N41E34CDD	McKay Over-burden	6.6	270	4.45	525
10M	2/8/77	2N41E34CDD	McKay Coal	4.0	15	12.83	390
10M	9/28/77	2N41E34CDD	McKay Coal	4.1	182	12.99	Est. 400*
12M	2/8/77	2N41E34DAC	McKay Coal	4.2	8	30.24	165
12M	10/5/77	2N41E34DAC	McKay Coal	1.44	231	17.04	95
14M	2/9/77	1N41E03BBD	McKay Coal	3.2	12	9.56	410
14M	10/6/77	1N41E03BBD	McKay Coal	1.58	215	3.12	556

*Test problem due to variable flow from bad valve. Value not used to calculate average transmissibility

15S	2/9/77	2N41E34CAC	McKay Over-burden	3.4	10	11.10	330
15D	2/9/77	2N41E34CAC	McKay Over-burden	3.9	12	20.61	230
210	2/9/77	2N41E29AAA	Sub McKay	3.3	14	39.89	90
121	2/9/77	2N41E29BCB	Sub McKay & McKay Coal	5.3	15	24.98	250
211	2/9/77	2N41E29ABA	Sub McKay	3.5	15	19.08	215

Water level Observations

Water levels were measured in all observation wells on approximately a monthly basis (Figures 3, 4 and 5, and Appendix I). Water level hydrographs were plotted to distinguish trends in the piezometric surface and water levels in the aquifers peripheral to the ponds. Significant losses of water from ponds should be reflected in rising water levels in the observation wells.

All available water level data from observation wells were obtained. Some of the data were from the Montana Power Company, and some from a contractor just after the wells were completed. Measurement technique and measuring points used in the early water level data are not well known. After initiation of this project, the water levels were accurately measured using a steel tape with the top of the well casing as a measuring point.

Water level thus far has shown a small decline during the summer and fall months, and a small rise in most wells occuring in mid-winter. This rise continued until late winter, at which time a decline was observed in most wells. A mid-winter rise in water levels seems unusual and no reasons for this rise are apparent. Van Voast, Hedges, and McDermott (1977) observed similar fluctuations in the Colstrip area from observation wells in both the alluvium and McKay Coal in 1975 and 1976, and the dates and magnitudes of rises observed in wells peripheral to the ponds are similar to those observed in other observation wells. Well 6-M has an unusual hydrograph (Figure 3). Water level in this well rose steeply from late summer to mid-winter with maximum rise of about 11 feet observed. This is thought to be the result of disposal of water from a nearby coal pit into a borrow pit located immediately south of test well 6-M. The amount of water disposed

Figure 3.

Water level hydrographs for monitoring wells in the Colstrip area.

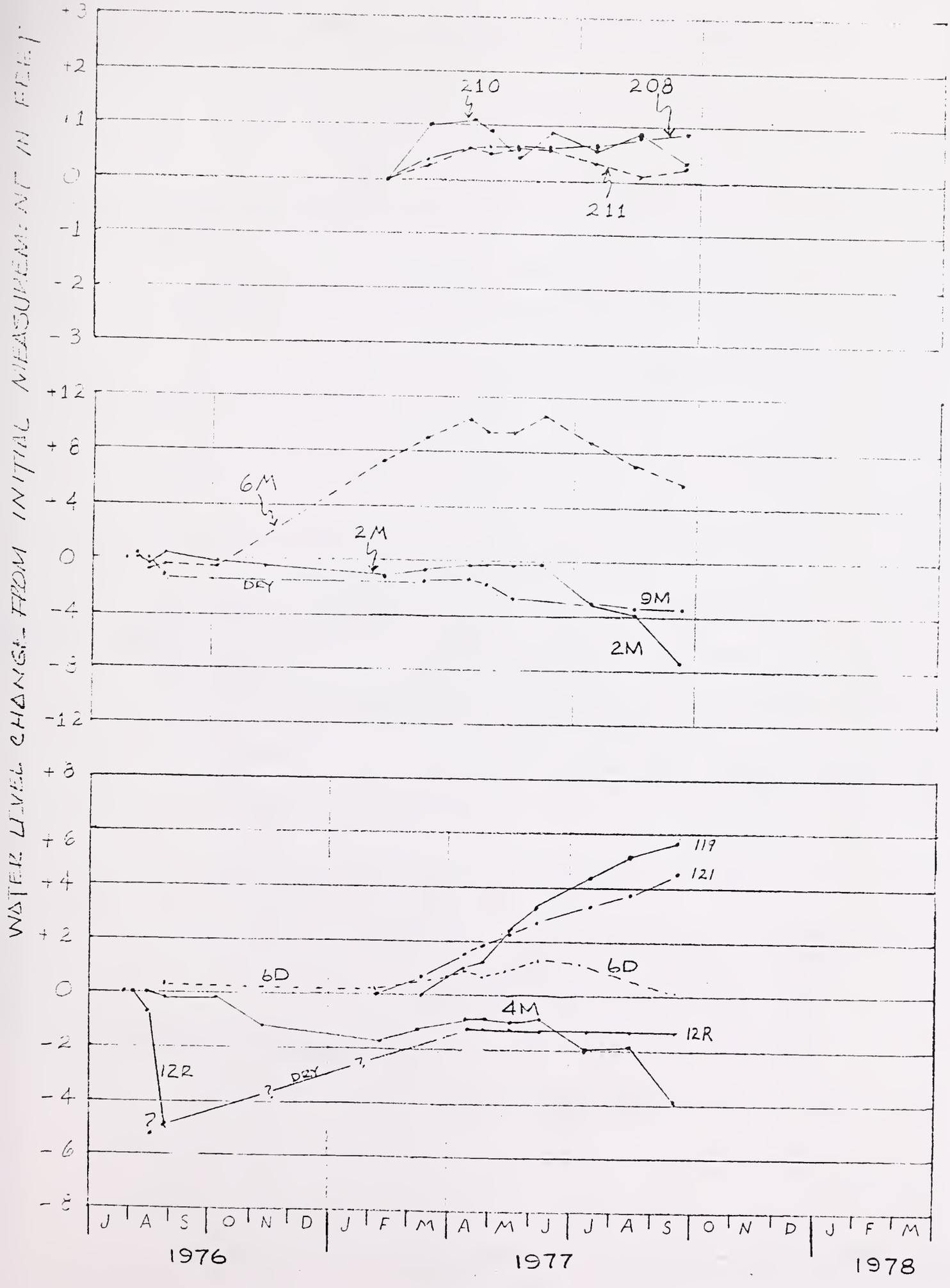


Figure 4.

Water level hydrographs for monitoring wells in the Colstrip area

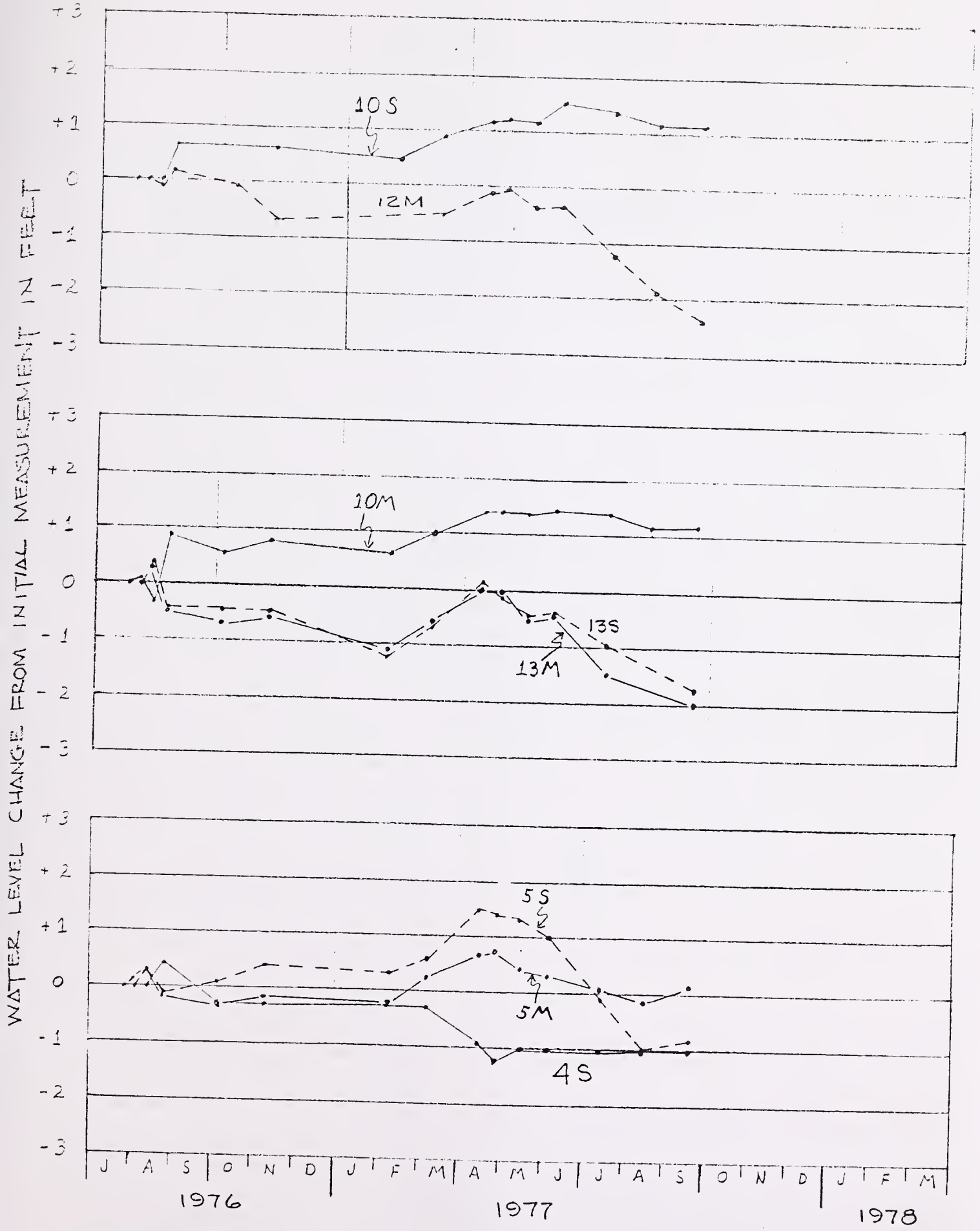
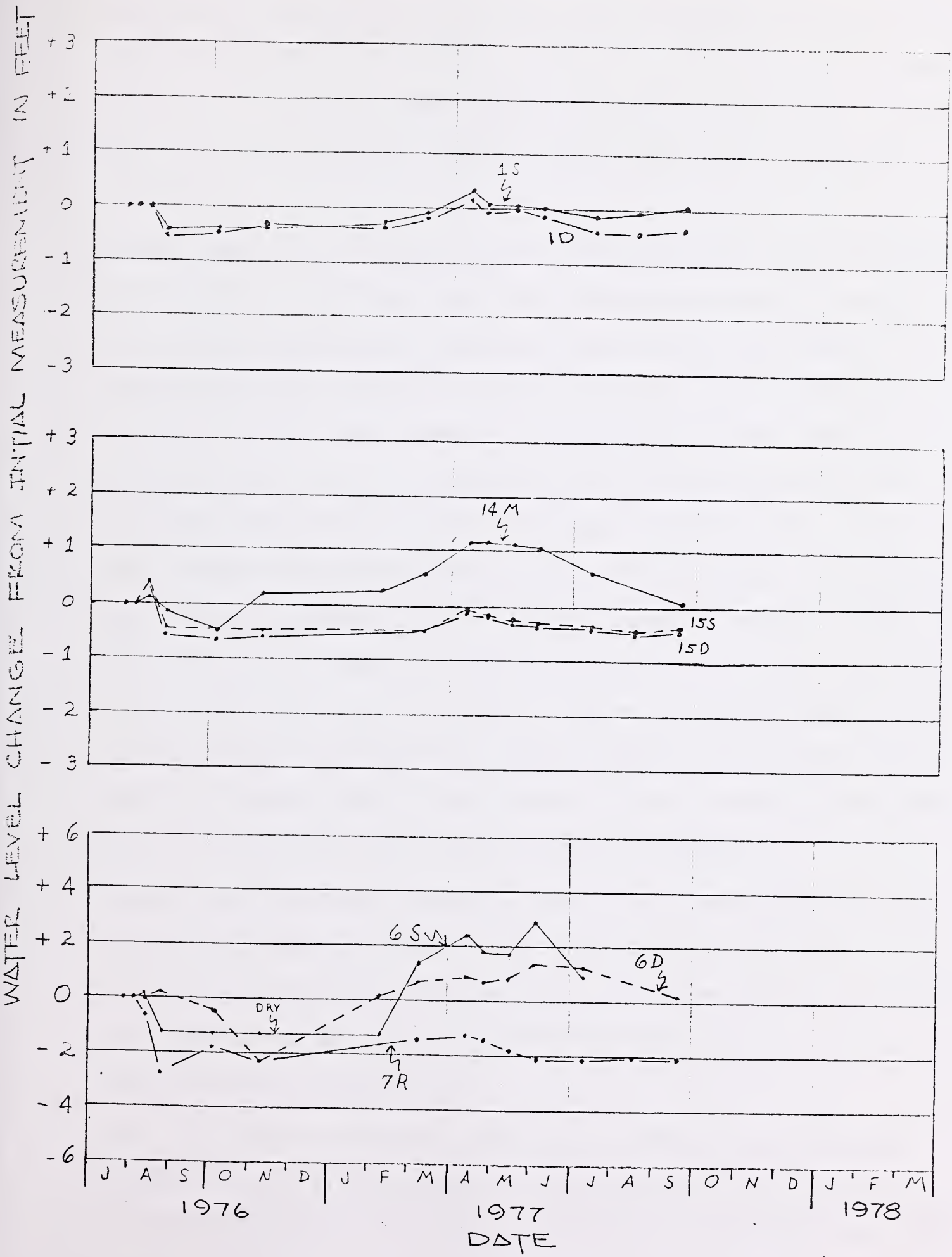


Figure 5.

Water level hydrographs for monitoring wells in the Colstrip area



in this area is unknown, and the disposal practice ceased in the spring of 1977, at which time the water level in 6 M began to decline. Hole 6D, which is adjacent to hole 6M, showed a minor fluctuation in water level, indicating a poor hydraulic connection between the McKay coal seam and strata below the McKay.

Another hydrograph of interest is at observation well 2M, in which from early summer to fall of 1977, the water level declined approximately six feet. This decline is attributed to excavation into the McKay coal seam for construction of the foundations for Colstrip plants 3 and 4 which began in late June, 1977. This excavation is located approximately 400 feet northwest of test well 2M. Observation wells 12M, 4M, 13M and 13S also show water level declines from the early summer to fall of 1977. These wells probably are reflecting the drop in hydraulic pressures in the McKay coal seam due to movement of water into the excavation northwest of 2M. This water level response shows good hydraulic continuity within the McKay coal and also shows some connection between the McKay coal and overlying strata in the vicinity of test hole 13S. There is, however, only 3 feet vertical separation between slotted casing sections in these two wells (13S and 13M), thus, it is not surprising to observe similar hydrographs.

Based on water level data collected to date, it is concluded that the McKay aquifer system underlying the pond area is hydraulically continuous and is sensitive to inflows and outflows of water. It appears that any significant water seepage from the pond systems would be reflected by a rise in water levels in wells in the McKay coal.

Water levels in five observation wells near the flyash evaporation pond (Figure 1) show no significant trend in wells 208,210, and 211 (Figure 3), but a rise of about 5.5 and 4.5 feet in wells 119 and 121 respectively (Figure 3).

There was no significant input of flyash slurry to the flyash evaporation pond during the early period of the hydrograph, but some runoff accumulated in the pond. These wells may be reflecting seepage from the flyash evaporation pond or from the nearby surge pond. The surge pond filled with water in June, 1972, whereas the flyash evaporation pond, as yet, contains little water. Static water level elevations in holes 119 and 121 are between 3255 and 3260. Elevation of the surge pond water surface is about 3270 and the evaporation flyash pond 3250. The flyash pond water surface thus is lower than water levels in monitoring wells 119 and 121. The rise in water levels, therefore, must be due to seepage from the surge pond.

Groundwater Movement

Groundwater moves in response to the slope of the water table or, in confined aquifers, to the slope of the piezometric surface. Groundwater moves at right angles to equipotential lines and parallel to the gradient (line of maximum rate of descent). The velocity of movement is a function of permeability and gradient; and, the volume of groundwater moving can be calculated by the equation:

$$Q = WTi$$

Where Q is the flow of water through an aquifer of width W with transmissibility T, under a gradient of i.

To assess the nature of movement from the Colstrip ponds, a piezometric contour map was drawn for the McKay aquifer (Plate I). The piezometric surface of this aquifer (Plate I) and its relationship to underlying geological structure, is poorly known due to lack of sufficient data for a structure contour map. The area of high groundwater may, however, be related to infiltration into burned Rosebud coal outcrop between wells 12R and 7R, or to infiltration into spoils east of the ponds. An alternate explanation would be seepage from the ponds, however, water levels (Figures 3,4,5), and specific conductivity graphs (Figures 11-14) and chemcial analysis (Table 3) do not substantiate this hypothesis.

Based on the piezometric surface and an average transmissibility of 238 gpd/ft. for the McKay aquifer, groundwater flow in this aquifer is calculated to be 1.4 gpm per 1000 feet of aquifer width.

A comparison of shallow aquifer (McKay overburden) and Rosebud aquifer water levels on the McKay aquifer piezometric surface map showed a good correspondence. This suggests a hydraulic connection between these aquifers. Based on water levels at paired wells, there is a small but variable difference in head

between water zones except at wells 12R and 12M, where there is a strong downward vertical gradient. This suggests the area around wells 12R and 12M may be a recharge zone.

Using an average gradient in the McKay aquifer as an approximate gradient for the McKay overburden, and using an average transmissibility of the McKay overburden of 757 gpd/ft., a flow in this unit of 4.5 gpm per 1000 feet of aquifer width is calculated.

The influence of water disposed in the borrow area south of well 6M is readily apparent on water levels in 6M. Water is entering the McKay aquifer, but is not entering the strata below the McKay except possibly through poor hydraulic connection.

Based on an average thickness of the McKay coal of 10 feet; an average transmissibility of 238 gpd/ft; an average gradient of .0075 (from Plate I), and an effective porosity of 0.05, the velocity of groundwater movement is about 0.5 ft/day and it would take an average water parcel about 1600 days to move from the edge of the flyash pond to the East Fork of Armells Creek. Velocity in the McKay overburden is about three times faster.

WATER QUALITY

Water quality at Colstrip includes quality of water in waste ponds, groundwater, the surge pond (Yellowstone River water), and the East Fork of Armells Creek. Of particular importance is the relationship of waste ponds and monitoring wells.

Waste Ponds

Quality of water in the waste ponds is related to interactions with flyash and bottom ash materials; concentration of treated Yellowstone River water in cooling towers, and physical and chemical reactions in the ponds. The major factor in flyash pond water quality is the reaction of water on flyash in the system. As described by Quilici (1973):

> Flyash can be defined as the fine particulate matter separated from flue gases resulting from the combustion of pulverized coal. It is an extremely complex, heterogeneous material exhibiting wide variations of chemical and physical properties. Its source is the original inherent extraneous mineral matter associated with a combustible coal.

Flyash physically consists of small, solid, or hollow spheres of fused glass and some unburned coal particles. When flyash is dry it is a very powdery, stable material, and according to Quilici (1973), generally 60 to 90 percent will pass a 325 mesh sieve. Coal from the Rosebud seam contains about 0.23 percent Na_2O, 5.42 percent MgO, and 20.1 percent CaO, and approximately 8.6 percent of the coal is ash.

Wall slag and bottom ash generally result when molten materials collide forming heavy particles that drop to the burner bottom. Their composition is similar to flyash, however, they have much less opportunity to interact with volatile constituents and gases which exit through the stack.

Typical water quality in all ponds at Colstrip is shown in Table 3 . Major constituents in the ponds are derived from dissolution processes involving

TABLE 3. TYPICAL WATER QUALITY OF WELLS, PONDS, AND STREAMS IN THE COLSTRIP, MONTANA AREA

Major Cations and Anions - Reported in mg/l except as indicated

Northern Testing Labs Data

WELLS Well Number	Oepth(ft)	Location	Date	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity (as $CaCO_3$)
1S	35.0	2N41E34CAA	9/21/77	395	364	262	9	715	0	586
1D	60.0	2N41E34CAA	9/21/77	159	112	143	9	538	0	441
2M	52.5	2N41E34DAA	9/21/77	91	46	60	4	434	0	356
4S	40.0	2N41E34DDA	DRY							
4M	77.6	2N41E34DOA	9/20/77	55	40	210	6	467	0	383
5S	31.0	2N41E34CDA	9/20/77	729	608	358	5	613	0	503
5M	47.6	2N41E34CAC	9/20/77	274	202	122	7	516	0	423
6S	27.5	1N41E03ACB	9/19/77							
6M	45.0	1N41E03ACB	9/20/77	248	333	92	7	626	0	513
6D	99.0	1N41E03ACB	9/20/77	173	120	114	9	583	0	478
7R	37.8	1N41E03ABO	9/20/77	405	244	121	11	670	0	550
9S	40.0	1N41E03ACA	DRY							
9M	60.0	1N41E03ACA	DRY							
10S	38.0	2N41E34CDO	9/20/77	414	422	260	10	390	0	320
10M	53.0	2N41E34CDO	9/20/77	188	158	118	8	395	0	324
12R	42.5	2N41E34DAC	DRY							
12M	75.0	2N41E34DAC	9/21/77	78	43	203	8	537	0	440
13S	24.0	2N41E34OBC	9/21/77	497	868	277	8	451	0	370
13M	37.5	2N41E34OBC	9/21/77	239	74	252	14	12	7	21
14M	34.7	1N41E03BBD	9/20/77	379	288	223	12	504	0	413
15S	40.0	2N41E34CAC	9/20/77	215	234	173	12	587	0	481
15O	60.0	2N41E34CAC	9/20/77	175	145	272	12	496	0	406
119	100.0	2N41E29DAA	9/19/77	272	331	100	12	4D3	0	331
121	95.1	2N41E28BCB	9/19/77	293	186	70	13	437	0	359
205	100.7	2N41E29BAA	ORY							
208	96.5	2N41E29BBO	9/19/77	89	82	157	7	458	0	375
210	98.0	2N41E29AAA	9/19/77	151	165	87	8	476	0	390
211	99.4	2N41E29ABA	9/19/77	251	186	286	11	476	0	390
PONDS										
Flyash Clear Return		2N41E34	1/11/77	667	1655	226	13	3	0	2
Wash Tray		2N41E34OBB	1/11/77	667	1699	152	12	-	-	-
Bottom Ash Clear Return		2N41E34OCA	1/11/77	600	227	248	15	D	30	99
Cooling Tower Blowdown		2N41E34	1/11/77	358	186	528	32	138	0	113
Flyash Evaporation		2N41E34	4/25/77	248	261	95	8.1	354	0	290
Fishing Pond		2N41E34CA	2/10/76	162	582	240	22	433	0	355
STREAMS										
East Fork Armells Creek										
Above Colstrip at HWY 315		1N41E3BBB	11/10/76	248	323	200	13	573	0	470
Below Colstrip (Flume B)		2N41E28AAD	11/10/76	377	381	295	14	449	0	368
YELLOWSTONE RIVER at Forsyth	Flow (CFS)									
	20,500	6N40E22AAO	5/10/76	47	19	42	3.0	181	0	148
	8,36D	6N40E22AAO	1/31/76	59	2D	59	3.4	189	0	155
	9,000	6N40E22AAD	10/21/75	55	21	51	3.2	185	0	152

TABLE 3.(continued)
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Well Number	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3-N)	Dissolved Solids Calculated	pH Units	Specific Conductance umhos/cm	Minor Constituents and Metals - Reported in mg/l dissolved except as indicated as total recoverable (TR) and total (T)					
								Iron (Fe)	Manganese (Mn)	Boron (B)	Cadmium (Cd)	Copper (Cu)	Lead (Pb)
1S	2369	32	0.2	0.33	4147	7.4	4170	.66	.57	1.4 (T)	<.001	.01	<.05
1O	714	9	0.2	0.04	1684	7.4	1920	.55	.30	.37(T)	<.001	<.01	<.05
2M	183	4	0.3	0.03	822	7.4	953	.30	.06	.19(T)	<.001	.01	<.05
4S													
4M	373	6	0.3	0.02	1157	8.0	1380	.14	.13	1.2 (T)	<.001	.01	<.05
5S	4422	30	0.2	2.26	6767	7.4	6240	.04	.06	1.5 (T)	<.001	<.01	<.05
5M	1302	12	0.2	0.02	2435	7.2	2600	.12	.50	.46(T)	<.001	<.01	<.05
6S								.04	.01	.42(T)	<.001	.01	<.05
6M	1590	18	0.3	8.62	2923	7.2	3040	.09	.02	.24(T)	<.001	<.01	<.05
6D	679	10	0.2	0.02	1683	7.3	1850	.20	.42	.49	<.002	.01	<.02
7R	1677	14	0.1	0.02	3142	7.2	3220	.06	.54	.68(T)	<.001	<.01	<.05
9S													
9M													
10S	2825	30	0.2	18.27	4369	7.7	4550	.09	.04	.25(T)	.001	.01	<.05
10M	1024	15	0.2	0.09	1906	6.9	2130	3.3	.27	.32(T)	<.001	<.01	<.05
12R													
12M	360	7	0.2	0.02	1236	8.3	1410	<.01	.09	.70(T)	.005	<.01	<.05
13S	4815	46	0.4	19.03	6981	7.7	6620	.02	.02	3.9 (T)	<.001	.03	<.05
13M	1373	23	0.1	0.02	1994	9.5	2400	.04	<.01	.16(T)	<.001	.01	<.05
14M	2135	15	0.1	2.07	3558	6.9	3660	.41	.72	1.0	<.002	<.01	<.02
15S	1340	13	0.2	0.03	2574	7.8	2770	.21	.20	.41(T)	<.001	.01	<.05
15D	1190	10	0.3	0.02	2300	7.5	2590	1.3	.04	.37(T)	<.001	<.01	<.05
119	1860	14	0.4	0.90	2993	7.7	3160	2.4	.49	1.2 (T)	<.001	.01	<.05
121	1254	11	0.9	1.70	1788	7.5	2420	1.7	.17	.65(T)	<.001	.01	<.05
205													
208	513	6	0.4	0.04	1312	7.9	1520	.22	.23	.33(T)	<.001	<.01	<.05
210	816	9	0.3	3.06	1715	7.7	1910	.01	.02	.92(T)	<.001	<.01	<.05
211	1575	18	0.2	0.02	2803	7.5	3090	.53	.81	.54(T)	<.001	.01	<.05
PONDS.													
Flyash Clear Return	8600	24	11.0	17.0	11216	4.9	9700	.28(TR)	29.(TR)	57.(T)	.019(TR)	.21(TR)	<.05(TR)
Wash Tray	8490	20	16.0	16.0	11072	4.2	9500	3.5 (TR)	34.(TR)	56.(T)	.020(TR)	.43(TR)	<.05(TR)
Bottom Ash Clear Rtn.	2688	66	0.52	6.5	3881	9.8	4036	.05(TR)	.08(TR)	28.(T)	.003(TR)	.02(TR)	.05(TR)
Cooling Tower Bldwn.	2496	92	6.0	0.40	3836	7.8	4246	1.4 (TR)	.15(TR)	1.1(T)	<.001(TR)	.51(TR)	<.05(TR)
Flyash Evaporation	1500	16	0.33	-	2483	7.4	2771	.02	<.01	1.0(T)	<.001	<.01	<.05
Fishing Pond	2850	25	0.15	0.06	4314	7.96	4464	.45(TR)	.35(TR)	.50(T)	.007(TR)	.02(TR)	.07(TR)
STREAMS													
E. Fork Armells Cr.								FLOW(cfs)					
Above Colstrip	1843	22	0.24	.33	3223	8.10	3510	.06	.67(TR)	.47(TR)	3.5(T)	<.001(TR)	<.01(TR)	<.05(TR)
Below Colstrip	2362	61	0.50	1.0	3940	7.90	3930	1.9	6.17(TR)	1.75(TR)		<.001(TR)	.01(TR)	<.05(TR)
YELLOWSTONE RIVER													
at Forsyth	120	6.5	.3	.42	338	8.0	540		.02	.00	.07	<.01	.002	.004
	190	8.9	.5	.42	444	8.4	675		.02	.01	.10	.00	.001	.001
	170	9.0	.4	.16	411	8.5	540		.00	.01	.15	.00	.001	.003

TABLE 3. (continued)
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Well Number	Zinc (Zn)	Selenium (Se)	Lithium (Li)	Vanadium (V)	Chromium (Cr)	Mercury (Hg)	Aluminum (Al)	Nickel (Ni)	Barium (Ba)
1S	.01	<.001	.02	<.10	<.05	.0002			
1O	.04	<.001	.05	<.10	<.05	<.0002			
2M	<.01	<.001	.02	<.10	<.05	<.0002			
4S									
4M	<.01	<.001	.03	<.10	<.05	<.0002			
5S	<.01	<.001	.10	<.10	<.05	.0002			
5M	.05	<.001	.04	<.10	<.05	.0002			
6S	.17	.041	.06	<.10	<.05	<.0002			
6M	.62	.074	.03	<.10	<.05	<.0002			
6O	<.01								
7R	.33	<.001	.06	<.10	<.05	<.0002			
9S									
9M									
10S	<.01	.085	.06	<.10	<.05	<.0002			
10M	.01	<.001	.04	<.10	<.05	<.0002			
12R									
12M	<.01	<.001	.04	<.10	<.05	.0003			
13S	.17	.017	.06	<.10	<.05	.0016			
13M	<.01	<.001	.06	<.10	<.05	<.0002			
14M	.04								
15S	<.01	<.001	.06	<.10	<.05	<.0002			
15O	<.01	<.001	.06	<.10	<.05	.0002			
19	<.01	<.001	.10	<.10	<.05	.0008			
21	<.01	<.001	.09	<.10	<.05	.0007			
205									
208	.10	<.001	.04	<.10	<.05	.0010			
210	<.01	.006	.04	<.10	<.05	<.0002			
211	<.01	<.001	.09	<.10	<.05	.0014			
PONDS									
Flyash Clear Return	.38(TR)	.175(TR)	1.1 (TR)	<.50(TR)	.05(TR)	<.0002(TR)		.57(TR)	
Wash Tray	.45(TR)	.255(TR)	1.0 (TR)	<.50(TR)	.08(TR)	<.0002(TR)		.42(TR)	
Bottom Ash Clear Return	.01(TR)	.009(TR)	.74(TR)	<.50(TR)	.05(TR)	<.0002(TR)		<.05(TR)	
Cooling Tower Blowdown	.21(TR)	.018(TR)	.23(TR)	<.50(TR)	<.05(TR)	<.0002(TR)		<.05(TR)	
Flyash Evaporation	.04	.028	.04	<.10	<.05	<.0002			
Fishing Pond	<.01(TR)	.009(TR)	.03(TR)	<.10(TR)	.01(TR)	.0014(TR)	.70(TR)	.06(TR)	<.10(TR)
STREAMS									
East Fork Armells Creek									
Above Colstrip at HWY 315	<.01(TR)	<.001(TR)	.08(TR)	<.2 (TR)	<.05(TR)	<.0002(TR)		<.05(TR)	
Below Colstrip (Flume B)	.03(TR)		.36(TR)	<.2 (TR)	<.05(TR)	<.0002(TR		.05(TR)	
YELLOWSTONE RIVER									
at Forsyth	.00	.001	.02	.0000	.01	.0000	.02	.004	
	.00	.002	.04	.0016	.00	.0002	.26	.002	
	.01	.001	.03	.0015	.00	.0000	.02	.005	

flyash, bottom ash and water, and reaction of SO_2 and water to produce sulfurous and sulfuric acid. These acids ionize in ponds and produce an acid pH and abundant sulfate ion.

During start up of the power units, adjustments in water flows in the various waste loops were required to obtain water balances in the system. This caused some intermixing of pond waters during early phases of the plant operation and minor amounts of intermixing still occur. The basic chemical characteristics of each of the ponds is distinctive, but some quality variations occurred (Table 3a).

The concentration of major cations in the ponds is controlled by a number of reactions including solubility of calcium sulfate, magnesium sulfate, and hydroxides of magnesium. Gypsum ($CaSO_4.2H_2O$) solubility in cold water of 0°C is equivalent to 656 mg/l and 705 mg/l calcium at 25°C (Perry and Chilton, 1973). This solubility probably exerts a significant control on the concentration of calcium present in the pond system and review of pond water data shows calcium concentrations generally near this equilibrium value. Magnesium is abundant in the flyash pond water, as compared to the bottom ash water. This probably reflects the high solubility of magnesium sulfate in an acidic solution. The relatively low concentration of magnesium compounds in bottom ash waters is probably related to the relatively low solubility of magnesium hydroxide and magnesium oxide in basic aqueous solutions.

Water entering the cooling tower blowdown pond is derived from softened Yellowstone River water. This water is concentrated by evaporation by a factor of 10 to 15 in the cooling towers and a portion of the water is removed and placed in the blowdown pond. Fresh make-up water replaces the

TABLE 3a. SELECTED WATER QUALITY STATISTICS FOR PONDS IN THE COLSTRIP AREA

POND	Specific* Conductance umhos/cm	SO_4 mg/l	pH units	Zinc, Total Rec. mg/l
FLYASH POND SYSTEM				
Number of samples	13	8	7	6
Maximum	10,053	9,400	7.3	.38
Minimum	3,493	5,150	4.6	.15
Mean	7,892	7,230	5.8	.25
WASH TRAY				
Number of samples	5	3	3	4
Maximum	9,600	8,958	4.20	.45
Minimum	6,616	5,640	3.93	.34
Mean	8,068	7,696	4.08	.46
BOTTOM ASH CLEAR RETURN				
Number of samples	7	4	5	5
Maximum	5,627	2,900	9.90	.01
Minumum	2,701	1,707	8.60	<.01
Mean	4,334	2,572	9.24	<.01
COOLING TOWER BLOWDOWN				
Number of samples	11	9	8	8
Maximum	4,671	2,760	9.10	.56
Minimum	3,193	1,750	7.77	<.01
Mean	4,065	2,314	8.36	.18
FLYASH EVAPORATION				
Number of samples	4	3	2	2
Maximum	9,319	8,333	8.50	.02
Minimum	8,551	7,860	8.20	.02
Mean	9,022	8,118	8.35	.02
FISHING POND				
Number	1	1	1	1
Maximum	4,464	2,850	7.96	<.01
Minimum	4,464	2,850	7.96	<.01
Mean	-	-	-	-

* Four of the 13 samples represent pond water quality during early transient state plant operations. By eliminating these four values, the mean conductivity is 8,773 umhos/cm, with a minimum equal to 7,109 umhos/cm. The maximum value remains 10,053 umhos/cm.

"blowdown" losses and quality is maintained to prevent precipitation and scaling in the cooling system. Minor amounts of sulphuric acid are added to the cooling tower circuit to control pH; a small amount of polyphosphate is added as a scale inhibitor and there is periodic shock chlorination.

Generally, flyash is enriched in volatile constituents relative to bottom ash. Water in the flyash ponds contains a higher concentration of dissolved material and much more sulfate than the bottom ash pond reflecting SO_2 capture in the flyash scrubber system. Fluoride (a volatile constituent) for example, is much more concentrated in flyash pond waters than in bottom ash pond waters.

In a study by the EPA (1975), it was found that waste waters associated with the Dave Johnson power plant pond were substantially enriched in calcium and sulfate. Ponds at the Dave Johnson plant, however, received unsegregated waters from the bottom ash and flyash and cooling tower blowdown, so they cannot be directly compared to those at Colstrip which have separate waste loops for each plant waste.

The washtray pond is similar in quality to the flyash pond; however, the flyash pond normally has a lower pH and a higher specific conductivity. This reflects the increased reaction in the washtray with SO_2 in the stack gas. Flyash is considered to have substantial alkalinity; however, the water associated with the flyash scrubber picks up considerable acidity. The resultant pH reflects the reaction of these two components. It is reported that resuspension or stirring of flyash in pond water will release additional alkalinity and raise the solution pH (C. Grimm, Montana Power Company, pers. comm., March, 1977). In August, 1977, a flyash slurry was pumped from the flyash ponds to the flyash evaporation pond. The pH of

the water when it arrived at the evaporation pond was 8.2 vs. a pH of 6.10 in the flyash pond. This suggests that the final pH of water in the flyash disposal pond will be basic as the pond fills. (Very little flyash had been slurried at the end of field work for this investigation).

The concentration of dissolved metals generally decreases as pH increases, thus, the overall impact of a pH increase should be improved water quality in the flyash evaporation pond.

In the acidic flyash ponds, manganese, boron, selenium, zinc, and fluoride, were present in concentrations well in excess of recommended limits for use in irrigation, public water supply or for freshwater aquatic life (Botz and Pedersen, 1977). Additional tests of these constituents showed them to be consistently high with boron 3.2 to 57 mg/l, zinc 0.02 to 0.38 mg/l, selenium 0.20 to 0.175 mg/l and manganese 5.5 to 29 mg/l.

Bottom ash pond waters are lower in major constitutents than the flyash ponds, metal concentrations are low and pH is high. The only constituent present in high concentrations is boron which ranged in concentration from 8.8 to 28 mg/l.

The blowdown pond contains more sodium, less calcium and magnesium than the ash ponds and has about the same sulfate and alkalinity as the bottom ash pond. The blowdown pond has concentrations of fluoride, copper, zinc and iron that are not high and are variable, but do exceed by several times recommended concentrations for some water uses.

The surge pond is Yellowstone River water. Typical seasonal water quality from the Yellowstone River near Forsyth (Table 3) shows the river to be a hard, calcium-sulfate-bicarbonate type, with a moderate to low concentration

of metals and nutrients. The water is suitable for all its prescribed uses including public water supply and aquatic life.

No chemical analyses of the brine disposal pond wastes were completed. A sample collected on August 25, 1977 showed a specific electrical conductivity of 64,821 umhos/cm at 25°C.

For comparison purposes, an analysis was made of water in the so called "fishing pond" (see Figure 1 for location). This pond is in an area of old mine spoils and water in the pond is groundwater. The pond reportedly was planted with trout each year and used for recreation by the community of Colstrip. The trout reportedly did not overwinter in the pond. As can be seen from Table 3, quality of water in this pond is poor and it is a very hard, magnesium-sulfate type, with a high concentration of dissolved minerals, and low metals except for iron, manganese and lead. Water quality in this pond is poor and it is higher in dissolved constituents than either the blowdown or bottom ash ponds, but lower in some metals.

Water in the East Fork of Armells Creek is very hard, alkaline, magnesium sulfate type and has a high concentration of dissolved minerals (Table 3). This water has low concentrations of most trace elements except iron, manganese and boron. Water quality of this stream is poor and it is not suited for irrigation, water supply, or most uses. The stream is classified as a B-D3 by the State of Montana which requires the stream to be suitable for growth and propagation of non-salmonid fishes. The stream, in its natural state, does not meet this classification.

Groundwater

Water samples were periodically (approximately monthly) taken from 27 monitoring wells peripheral to the waste ponds. Typical results of these analyses (Table 3) and Appendix III show the quality in the McKay coal and McKay overburden. In addition, two holes are in the Rosebud coal and one is completed beneath the McKay coal. Water quality is variable in the area but generally the waters are a magnesium-sulfate type with some calcium-sulfate, calcium-bicarbonate, sodium-sulfate, and sodium-bicarbonate types. The waters are all very hard, and alkaline with moderate to high concentrations of dissolved minerals. Trace element concentrations are generally low with some iron, manganese, zinc, and boron concentrations that exceed some recommended concentrations for some uses (Botz and Pedersen, 1977). Results of groundwater analysis work in the Colstrip area by Van Voast, Hedges, and McDermott (1977)(Table 4) showed qualities similar to that present in the pond area and trace element concentrations of iron, manganese, zinc and boron were high in some wells.

An excellent indicator of overall water quality is conductivity (specific electrical conductivity) which is a measure of the ions in solution and relates to the concentration of dissolved minerals. Figures 6 through 9 show conductivity versus time for all wells measured during this investigation. Generally, conductivity in the groundwater is much less than in the flyash ponds and less than the blowdown or bottomash ponds. The exception to this is in wells 1S, 5S, 10S, 13S, where conductivity in these wells is about equal to or greater than that of the bottomash or blowdown ponds.

Table 4--Chemical analyses of waters from observation wells near Colstrip, southeastern Montana.

Location	Designation	Well depth (feet)	Date sampled	Temperature (degrees C)	Silica (SiO2) (mg/L)	Iron (Fe) (ug/L)	Manganese (Mn) (ug/L)	Calcium (Ca) (mg/L)	Magnesium (Mg) (mg/L)	Sodium (Na) (mg/L)	Potassium (K) (mg/L)	Bicarbonate (HCO3) (mg/L)	Carbonate (CO3) (mg/L)	Sulfate (SO4) (mg/L)	Chloride (Cl) (mg/L)	Fluoride (F) (mg/L)	Nitrogen, Dissolved nitrate (as N) (mg/L)	Hardness as CaCO3 (mg/L)	Hardness, Noncarbonate (mg/L)	Alkalinity as CaCO3 (mg/L)	Sodium adsorption ratio	Specific conductance (micromhos at 25 C)	pH (units)	Source
2N 41E 28AAAA	P-13	23	05 16 75	9.5	27	1100	1440	290	110	250	11	634	0	1200	18	0.1	0.05	2000	1800	520	5.6	4100	8	
"	"	21	04-06-76	11.0	21	58	57	221	295	276	14	632	0	1200	19	.2	1.11	2420	1900	460	5.5	4100	8	
2N 41E 28AAAA	P-32	26	05 16 75	7.0	19	03	28	253	106	251	11	573	0	1040	32	2	1.07	1170	530	430	5.1	4200	7.6	Spoils
2N 41E 34DDAD	W-024	23	01-23-74*		17	3	43	481	248	23	13	693	0	1060	50	1	0.2	1640	1160	512	1.1	5140	7.4	
"	"	22	05-23-74	12	14	03	1130	497	231	130	16	625	0	1000	54	1	1.1	1610	1110	511	1.3	4950	7.2	
2N 41E 35B1BB	W-034	23	01-23-74*		22	6	12	143	200	52	15	508	0	1000	12	1	2.5	1600	1200	398	1	1920	7.1	
2N 41E 35DAAA	W-035	36	01-23-74*		19	11	530	190	470	81	14	411	0	2200	12	1	2.5	1070	842	454	4.5	3300	7.6	Mckay coal
2N 41E 35DABA	S-12	43	09-25-73		14	0.26	1100	54	58	190	8.1	535	0	264	4.0	1	0.2	1130	736	425	2.4	1780	7.8	
2N 41E 35DABB	S-13	43	09-25-73		15	08	98	114	104	136	8.2	542	0	652	5.9	0.1	0.2	1350	960	506	2.9	2410	8	
"	"	43	02-06-74		13	0.10	23	199	115	141	8.8	620	0	745	7.2	1	2.08	1550	960	460	2.2	2840	7.8	
"	"	43	06-06-74		13	<.01	3	196	111	140	8.2	639	0	714	5.8	1	1.11	1480	1010	501	1.9	2700	8	
"	"	43	02-04-75	10.0	16	<.01	1	196	111	140	8.2	631	0	800	7.0	1	1.11	1650	1100	501	1.9	2700	7.8	Rosebud coal
"	"	43	08-12-76	11	15	02	36	226	132	141	8.8	683	0	1020	10	1	1.61	1650	1100	560	2.0	2900	7.8	
2N 41E 35DABB	S-13	24	09-25-73		16	1.8	3.3	467	158	114	9.0	683	0	1030	14	.7	2.26	1200	1020	551	1.1	3500		
"	"	24	02-06-74		17	0.02	1170	421	306	119	9.9	737	0	1000	13	1	1.61	1200	1160	624	1.1	3600	7.1	
"		24	06-06-74		18	01	1.8	464	292	119	9.5	717	0	1020	13	1	1.61	1200	1160	624	1.1	3600	7.1	
"		24	02-04-75	9.0	11	01	1100	111	199	91	7.1	196	0	1420	85	2	1.32	2250	2080	126	0.6	2540	8.1	
"	"	24	01-12-76	10	13	03	1.69	5100	366	119	9.6	366	0	2100	15	1	1.16	1300	2360	464	1.0	3300	7.0	Mckay coal
2N 41E 01BCAB	S-11	59	09-25-73		11	0.34	1.6	21	12	420	10	591	0	1000	19	2	2.3	1760	1460	484	2.2	2900	7.2	
"	"	59	06-06-74		14	<.01	<.01	112	63	163	10	534	0	1000	11	1	1.8	2000	1800	426	1.0	3200	8.0	
2N 41E 01DDAA	S-08	43	09-25-73		21	08	118	149	246	123	25	156	0	2000	11	1	1.41	2900	2850	110	1.0	4200	7.6	
"	"	48	06-06-74		17	<.01	24	179	309	116	22	402	0	1600	12	1	0.91	2400	2350	516	1.5	3400	8.0	Spoils
2N 41E 01CADD	W-04	32	03-23-73*		21	15	2.2	343	117	96	17	429	0	1300	17	1	0.9	2360	1900	704	1	3400	7.1	
"	"	32	10-01-73		14	48	0.64	283	282	65		611	0	1400	28	2	2.53	2300	2020	352	0	3400	8.1	
"	"	32	01-12-76	10	13	03	86	336	341	78	20	910	0	1400	26	2	1.24	2200	2050	372	0.6	3300	7.7	
"	"	32	04-06-76	12.5	11	1.3	116	313	347	63	16	693	0	1520	26	2	1.71	2050	1870	489	1.2	3300	7.5	Mckay coal
2N 41E 04AABB	P-06	50	05-16-73	9.5	21	H01	12	213	199	1240	7.2	594	0	1200	11	2	2.3	2400	1850	482	1.7	3200	7.5	Alluvium
2N 41E 04AABB	P-05	33	05-16-73	7.5	23	01	<.01	214	184	143	8.5	576	0	1100	11	2	1.01	2300	1820	503	1.0	3420	8	
2N 41E 04AADB	P-03	34	05-16-73	10	23	<.01	01	216	264	162	12	664	0	1400	15	2	1.07	2400	1820	556	1.0	3600	7.4	
"	"	34	04-06-76	13.5	24	04	01	216	268	169	12	628	0	1400	15	2	1.41	2400	1870	496	1.0	3600	7.2	
2N 41E 04AADB	P-04	20	05-16-73	14	22	01	01	251	276	173	11	605	0	1350	12	2	1.64	2450	1940	504	1.2	3600	7.2	
2N 41E 04AADB	P-02	36	04-05-75	10	21	<.01	02	165	268	152	11	615	0	1340	12	2	1.32	1950	1420	1.43	1.4	2250	8.1	
2N 41E 04AADB	P-01	33	07-12-74		21	<.01	<.01	134	216	136	9.0	484	0	1140	12	2	1.32	1900	1400	492	1.4	2600	7.6	
2N 41E 04ADAA	P-01	35	05-16-73	10	23	01	03	181	231	121	9.1	500	0	1100	12	2	1.32	1900	1500	668	2.5	2900	7.2	McKay coal
2N 41E 10AACD	S-22	149	05-28-75	10	11	03	17	294	195	220	11	815	0	1200	8.9	1	0.53	1900	1560	353	1.0	2900	7.2	Rosebud coal
2N 41E 10AACD	S-28	130	05-16-75	11	12	1.0	0.16	141	248	91	6.1	923	0	919	3.0	1	0.2	1300	1060	640	1.0	2220	7.2	
"	"	130	09-30-75		12	18	17	114	261	85	5.3	383	0	869	9.3	1	1.4	1200	1000	614	1.0	2100	7.9	Mckay coal
2N 41E 12ADDD	S-06	50	09-25-73		15	06	11	109	92	59	5.1	363	0	444	6.6	1	1.4	916	653	414	1.1	1800	8.1	"
"	"	50	06-06-74		21	<.01	11	37	58	23	1.4	164	0	184	3.6	1	2.3	534	401	298	0.5	1100	8.3	"
2N 41E 16BAB	S-18	248	02-12-74		10	<.01	<.01	43	41	282	6.0	440	0	384	7.6	1	2.3	871	292	361	9.2	1310	8.3	
2N 41E 16BAB	S-19	225	07-12-74		12	<.01	<.01	47	83	114	4.9	429	0	384	6.4	1	1.8	814	264	352	2.1	1540	8.0	Rosebud coal
"	"	225	05-13-75	14	14	<.01	<.01	13	18	122	5.1	552	0	567	2.1	1	1.4	854	466	454	1.5	1280	7.6	
2N 41E 21DABB	BS-24	121	04-05-76	14	16	14	24	191	120	42	5.1	589	0	1200	10	1	0.2	1300	1060	511	1.5	1900	7.2	McKay coal
2N 41E 21DABB	BS-03	136	10-01-75		12	02	07	195	166	152	11	625	0	1000	11	1	1.11	1200	1020	451	1.0	1800	7.8	Alluvium
2N 41E 24CAAD	BS-14	31	08-28-75	10	10	02	01	262	246	410	10	598	0	1200	12	1	0.91	1200	1000	491	1.1	2020	7.6	
2N 41E 24CABB	BS-12	23	08-28-75	11	9.2	01	1.01	142	246	174	6	526	0	1000	11	1	0.58	1000	1000	431	1.1	1800	7.8	
2N 41E 24DBB	BS-13	22	08-28-75	13	18	05	01	207	138	216	8.2	419	0	1000	11	1	1.01	1200	1200	369	1.0	2.00	7.8	
2N 41E 25ABB	BS-21	23	08-28-75	13	7.9	03	02	124	221	2.8	8.4	461	0	1000	11	1	2.26	1100	1100	343	1.0	1900	7.6	Spoils
2N 41E 27AADD	S-10	40	09-25-73	-	13	05	02	231	360	191	6.4	418	0	1200	11	2	4.52	1800	1400	338	1.2	1900	7.7	
"	"	40	02-04-74		16	02	02	192	384	209	6.2	433	0	1200	11	2	4.52	1200	1020	336	1.0	1800	7.5	
"		40	06-06-74		15	01	01	128	143	171	6.4	427	0	1200	15	2	4.71	1200	1060	385	1.0	1800	7.6	
"	"	40	02-05-75	8.0	16	01	01	231	417	246	9.1	458	0	1200	11	1	2.21	1200	1000	234	1.1	1700	7.7	Alluvium
2N 41E 27AADD	S-17	16	02-04-74		15	1.1	01	402	924	508	28	184	0	1400	11	1	1.11	2000	1800	537	2.5	3000	7.6	Mckay coal
2N 41E 27ADCC	BS-21	97	04-05-76	12.5	14	1.5	25	219	228	218	9.4	316	0	1400	16	2	1.07	1200	1000	324	2.6	1800	7.6	Spoils
2N 41E 27ADCC	BS-22	38	04-05-76	12	11	0.77	2.8	430	225	211		619	0	1390	26	2	1.07	1200	1000	324	2.6	1800	7.6	Spoils
2N 41E 27ABCC	BS-20	97	10-01-75	-	14	03	0.18	216	233	223	15	580	0	1520	32	2	< 02	2320	1520	476	2.5	4100	7.8	Mckay coal
2N 41E 27BADC	BS-19	83	04-03-76	14.5	13	05	1.6	183	455	182		727	0	2420	28	2	0.73	1960	1820	744	1.4	4210	7.8	Mckay coal
2N 41E 27DAAC	S-14	51	09-25-73	-	12	04	0.02	114	464	167	10	541	0	2360	24	2	2.9	1110	1020	443	1.3	3250	7.7	"
"	"	51	02-04-74	-	14	02	06	146	426	173	9.0	511	0	2460	23	2	2.9	1180	1020	380	1.4	4140	7.4	
"	"	51	03-21-74	12	16	05	33	415	421	169	9.3	708	0	2380	25	4	2.9	1280	1270	380	1.4	4080	7.7	"
"	"	51	01-26-75	9.0	15	01	04	174	456	176	9.3	575	0	2350	23	2	0.9	1080	1020	622	1.4	4200	7.7	"
"	"	51	01-13-76	9.0	14	03	20	437	476	176	9.2	765	0	2370	23	3	1.2	1080	1020	626	1.4	4080	7.6	"
"	"	51	04-05-76	12.5	14	1.2	26	428	452	172	9.0	738	0	2510	25	1	0.3	1290	1090	605	1.4	4200	7.8	Spoils
2N 41E 27DACA	TW-1	74	04-13-76	10.5	9.6	0.03	1.6	405	158	116		859	0	1960	27	1	0.2	1320	1090	705	1.0	3230	7.8	Spoils

Site designation	Location	Date of sample collection	Mine area	Aluminum (Al) (ug/L)	Antimony (Sb) (ug/L)	Arsenic (As) (ug/L)	Beryllium (Be) (ug/L)	Boron (B) (ug/L)	Cadmium (Cd) (ug/L)	Chromium (Cr) (ug/L)	Copper (Cu) (ug/L)	Lead (Pb) (ug/L)	Lithium (Li) (ug/L)	Mercury (Hg) (ug/L)	Nickel (Ni) (ug/L)	Selenium (Se) (ug/L)	Silver (Ag) (ug/L)	Strontium (Sr) (ug/L)	Tin (Sn) (ug/L)	Zinc (Zn) (ug/L)	Site description
Ground waters from undisturbed aquifers																					
P-8	1N 41E 15DDDB	04-14-76		<.05	<.2	<2	<5	33	<.01	<.01	.01	.02	.06		.06	4.5	<.01	4.18	33	.02	Alluvium along Little Arnells Crk 7 mi upstream from Colstrip
P-1	1N 41E 04AADB	04-06-76		<.05	<.2	<2	<5	50	<.01	<.01	<.01	.006	.06		.02	<.5	<.01	4.85	28	.01	Alluvium along Little Arnells Crk 1 mi upstream from Colstrip
P-11	1N 41E 28AAAC	04-06-76		<.05	<.2		<5	.22	<.01	<.01	.01	<.008	.08		.06	<.2	<.01	7.11	43	.01	Alluvium along Little Arnells Crk 1 mi downstream from Colstrip
08CBAB	1N 41E 08CBAB	04-01-23				<2		<1	<.01	<.02	<.02	<.05		<.3	<.04	<5				.10	Rosebud coal upgradient from Rosebud mine
S-28	1N 41E 10AACD	09-30-75		.03	<.2	<2	<5	23	<.01	<.01	.01	<.05	.04	<.3	.03	<.2	<.01	2.05	25	.03	"
BS-04	1N 41E 21DADC	04-05-76		<.05	<.2	2.5	<5	20	<.01	<.01	<.01	.01	.03		.04	<.2	<.01	2.45	31	.01	Rosebud coal upgradient from Big Sky mine
BS-03	1N 41E 21DADD	10-01-75		<.05	<.2	<2	<5	46	<.01	<.01	.01	.07	.05	4	.01	<.2	<.01	12.01	17	.13	McKay coal upgradient from Big Sky mine
08BBDC*	1N 41E 08BBDC	03-19-73				<2		<1	<.01	<.02	<.02	<.05		<.3	<.04	<5				.05	Sandmine 200 ft below McKay coal
Ground waters from aquifers in and very near to mined lands																					
S-06	1N 41E 12ADDD	09-25-73	"			<2		58				.02				<.2					Water from McKay coal beneath mined area
S-09	1N 41E 01BDAC	09-25-73	Rosebud			<2		112	.01	<.02	<.02	.06			<.05	<.2				<.02	"
S-11	1N 41E 01BCAB	09-25-73	"			<2		54	.01	.02	<.02	<.02			<.05	<.2				<.02	"
S-12	2N 41E 35DABD	09-25-73	"			<2		125	<.01	<.02	<.02	<.02			<.05	<.2				<.02	"
S-13	2N 41E 35DABB	09-25-73	"			<2		114	<.01	<.02	.02	.20			<.05	<.2				.06	Water from Rosebud coal downgradient from mined area
EPA-03	1N 42E 18DAAA	04-14-76	"	<.05	<.2	<2	<5	31	<.01	<.01	<.01	<.05	.03		.06	<.2	<.01	3.19	23	.02	Water from mine spoils
W-02*	2N 41E 34DDAA	03-23-73	"			<2		12	<.01	.02	.02	.19		<.3	.14	<5				.19	"
W-03*	2N 41E 35BCBB	03-23-73	"			<2		96	<.01	<.02	.03	.13		<.3	.06	<5				.84	"
W-04*	1N 41E 03AABB	03-23-73	"			<2		120	<.01	<.02	<.02	.16		<.3	.08	<5				.27	"
"	"	10-01-73	"	.10	.30	4.4	<5	34	<.01	<.01	.01	.06	.07	<.3	.04	<.2	<.01	3.26	33	.03	"
"	"	04-06-76	"	.23	<.2		<5	.34	.01	.01	.11	.12	.03		.07	<.2	<.01	3.70	33	.86	"
W-05*	2N 41E 35CBAA	03-23-73	"			<2		46	<.01	.02	.03	.19		<.3	.10	<5				.45	"
S-14	1N 41E 27DAAC	04-05-76	Big Sky	<.05	<.2		<5	38	<.01	.02	<.01	.13	.06		.09	<.2	<.01	1.22	40	.09	Water from McKay coal beneath mined area
BS-19	1N 41E 27BADC	04-05-76	"	<.05	<.2	<2	<5	24	<.01	.01	.01	.13	.09		.12	<.2	.01	6.61	46	.01	Water from mine spoils
BS-20	1N 41E 27ABCC	10-01-75	"	.11	<.2	<2	<5	55	<.01	<.01	.01	.06	.05	<.3	.04	<.2	<.01	9.01	35	.04	Water from McKay coal beneath mined area
BS-21		04-05-76		<.05	<.2		<5	36	<.01	<.01	.01	.11	.08		.11	<.2	<.01	7.21	28	.01	"
BS-22		04-05-76		<.05	<.2	<2	<5	55	<.01	.02	.02	.21	.08		.11	<.2	.01	6.51	28	.04	Water from mine spoils

Concentrations in mg/L (milligrams per liter) and ug/L (micrograms per liter) as noted
Reported values are for dissolved constituents only
Samples collected and analyzed by Montana Bureau of Mines and Geology except as noted
*Samples collected and analyzed by Westinghouse Electric Corporation (1973)

Source: VanVoast, Hedges, and McDermott, 1977.

Figure 6.

Specific conductivity in wells versus time

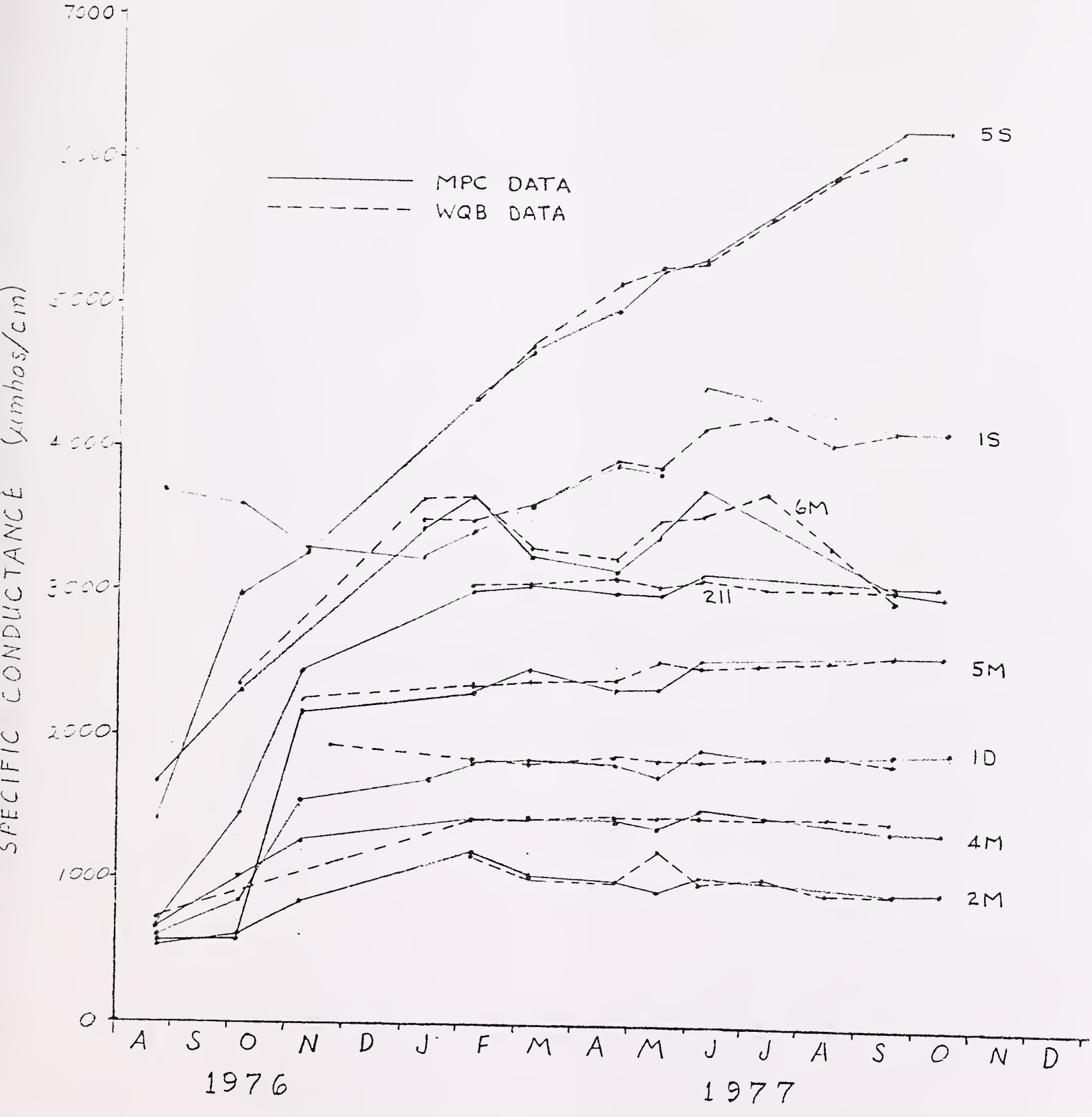


Figure 7.

Specific conductivity in wells versus time

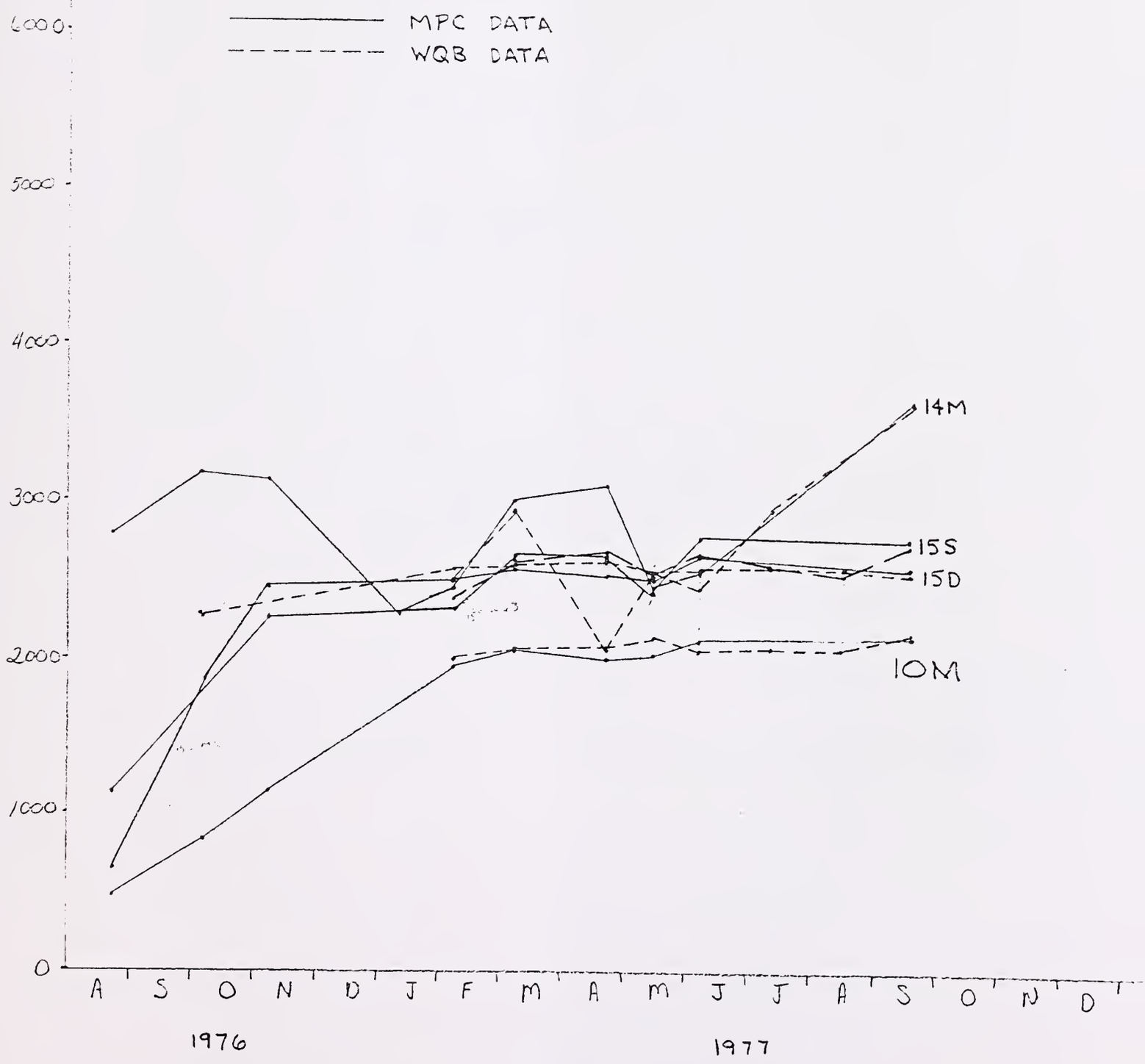


Figure 8.

Specific conductivity in wells versus time

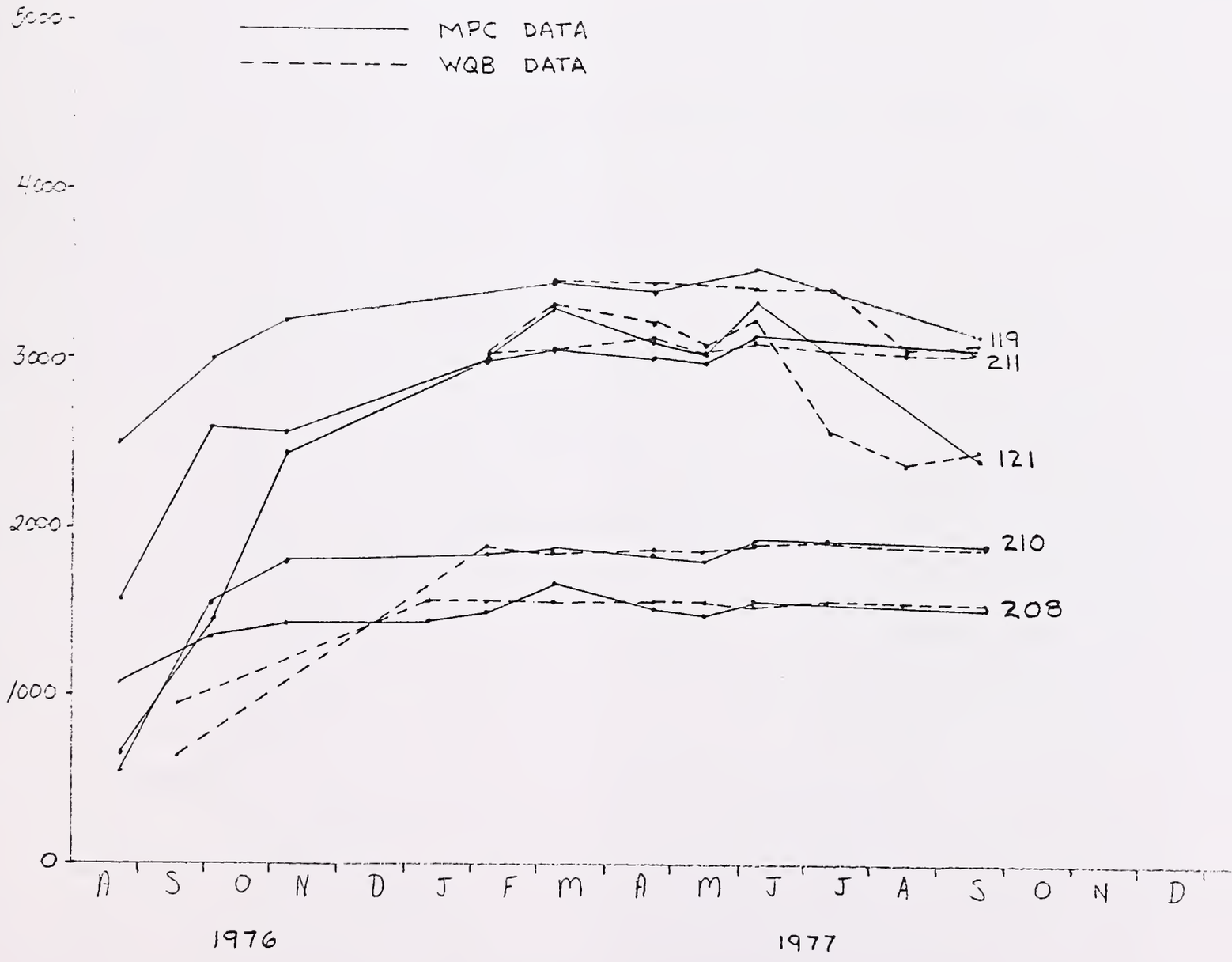
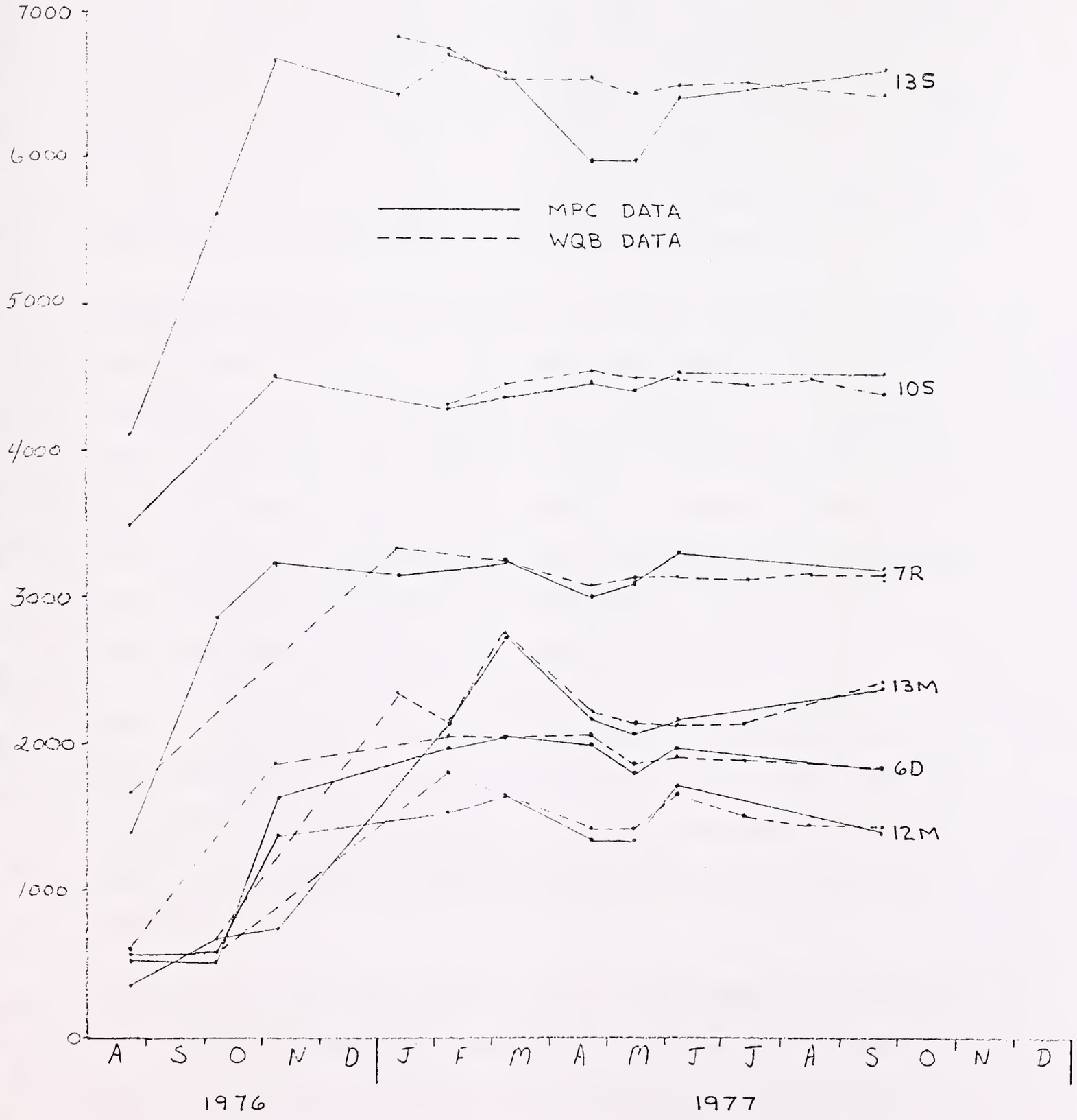


Figure 9.

Specific conductivity in wells versus time



A significant feature of the conductivity curves is the gradual increase in the early part of the investigation and leveling off after several months. This occurred on all or nearly every well. A possible explanation would be seepage from the ponds into the wells causing an increased conductivity in the wells. The wells however, are completed at different depths in different horizons and at different distances from the ponds. It seems unlikely that seepage would reach all the wells at about the same time and increase conductivity by about the same amount.

Another possible explanation involves Yellowstone River water that was used to flush the monitoring wells after construction. This water has a low conductivity and was injected into all the wells. It is possible that a slug of this water remained in the wells and slowly dissipated by dilution, reaction with aquifer materials, movement away from the well, and removal during sampling. The low permeability of the aquifers would not allow rapid movement of injected water and the slug of Yellowstone River water would be created in the aquifer.

Near the flyash evaporation pond, conductivity in the five monitoring wells showed the same pattern as near the plant ponds. Since there was no possibility of wastes reaching these wells, the conductivity changes must have been related to introduction of Yellowstone River water into the wells.

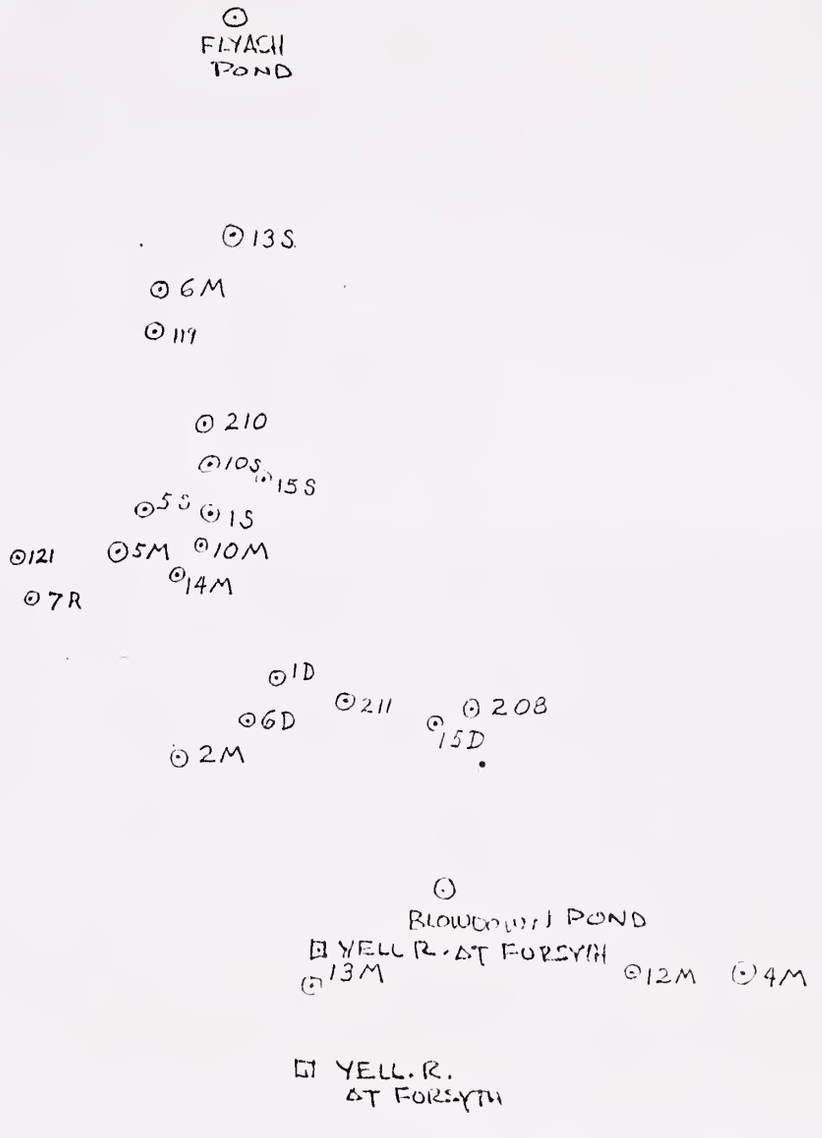
Major cations in all ponds and wells are calcium, magnesium and sodium. A trilinear plot of percentage abundance of cations (Figure 10) shows most wells to have a percentage cation composition intermediate between the three ponds.

The relationships of major ions and conductivity are shown in Figures 11 to 14. From these it is clear that magnesium-sulfate is responsible for the majority of the conductivity increase in the higher conductivity waters. Sodium and bicarbonate increase little as conductance increases, and calcium increases much less rapidly than does magnesium.

MAGNESIUM

Figure 10.

Trilinear plot showing relative abundance of cations in wells and waste ponds at Colstrip



CALCIUM

SODIUM + POTASSIUM

Figure 11.

Specific conductivity in wells versus bicarbonate and sulfate concentrations

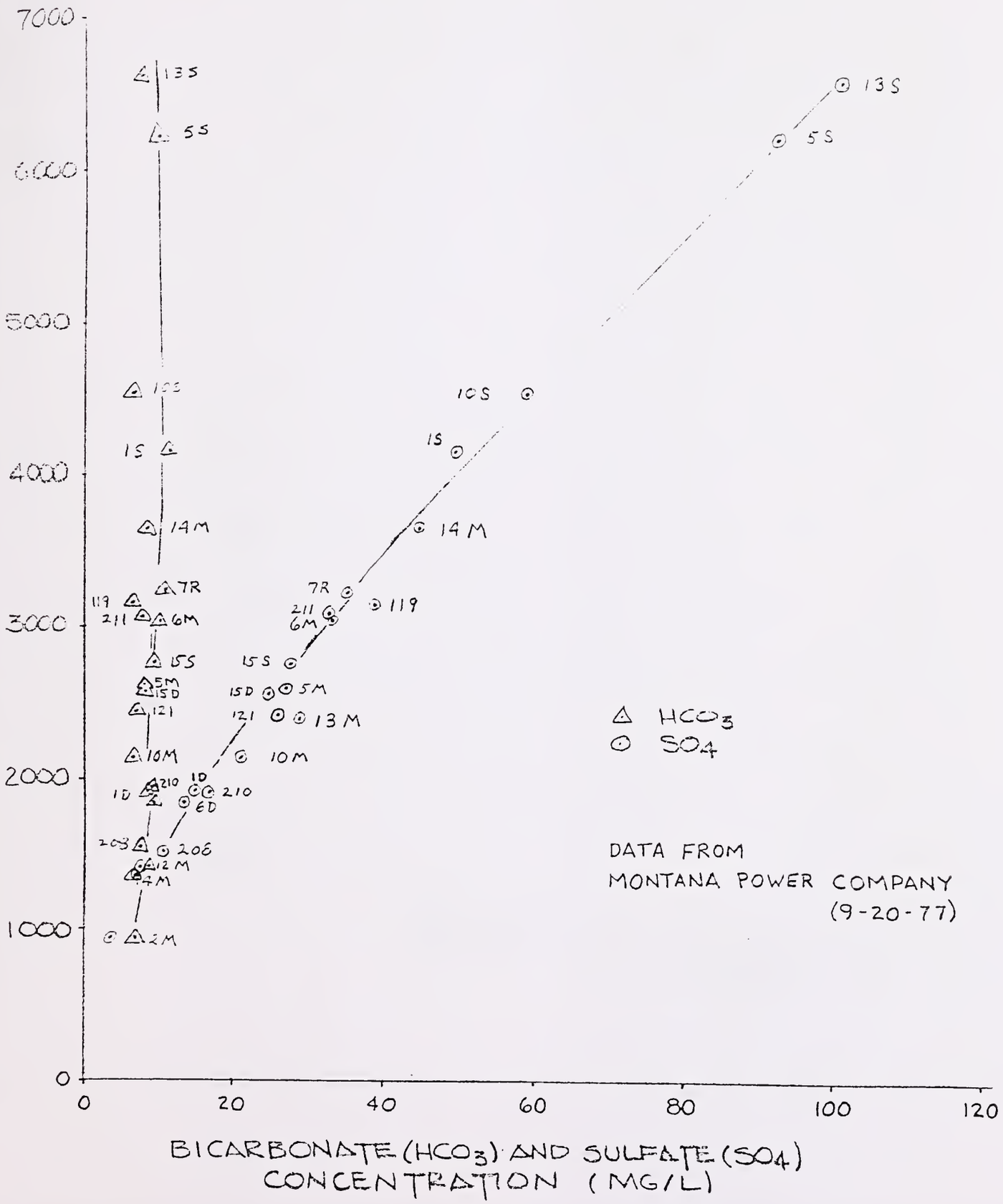


Figure 12.

Specific conductivity in wells versus sodium concentration

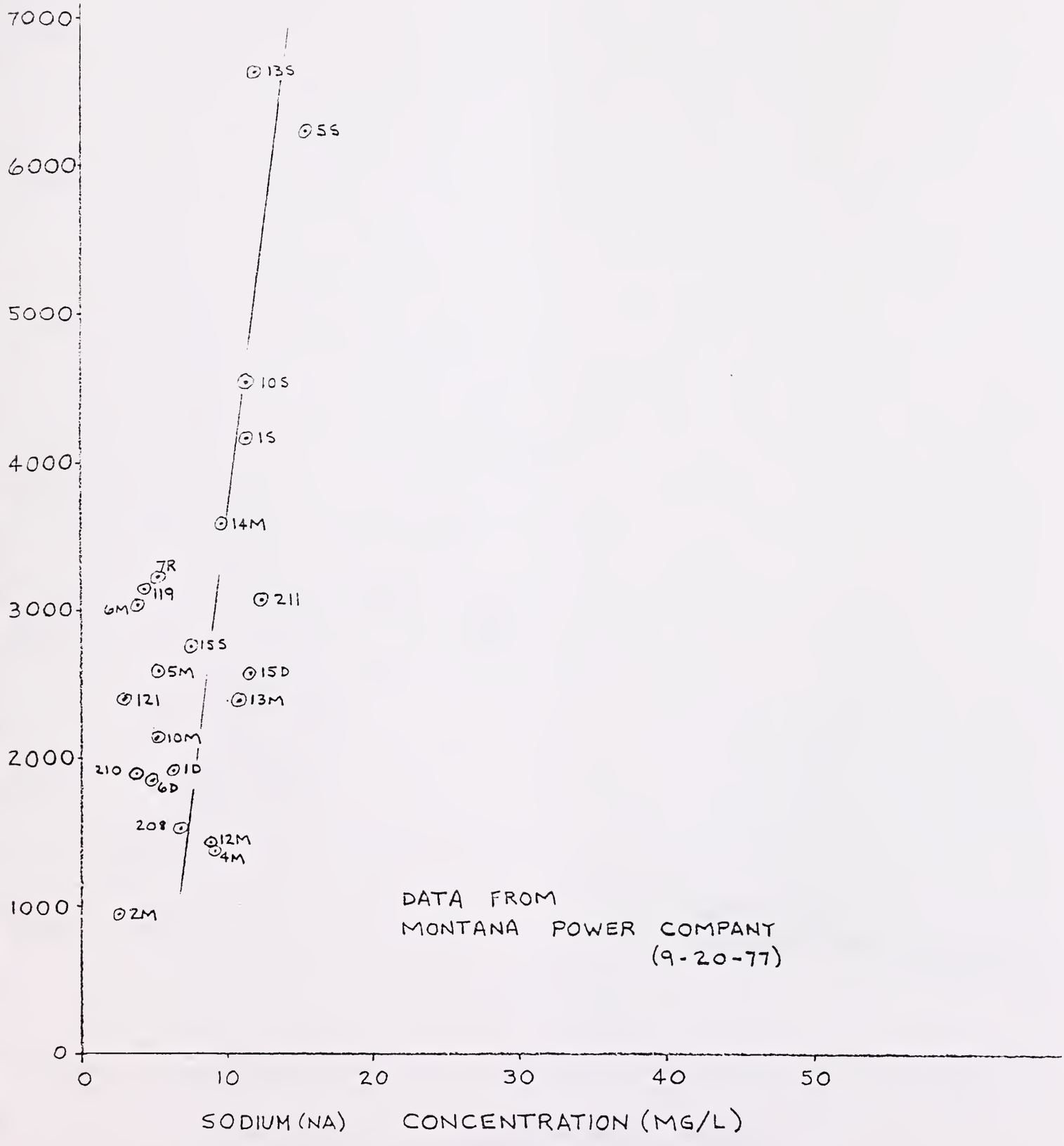


Figure 13.

Specific conductivity in wells versus magnesium concentration

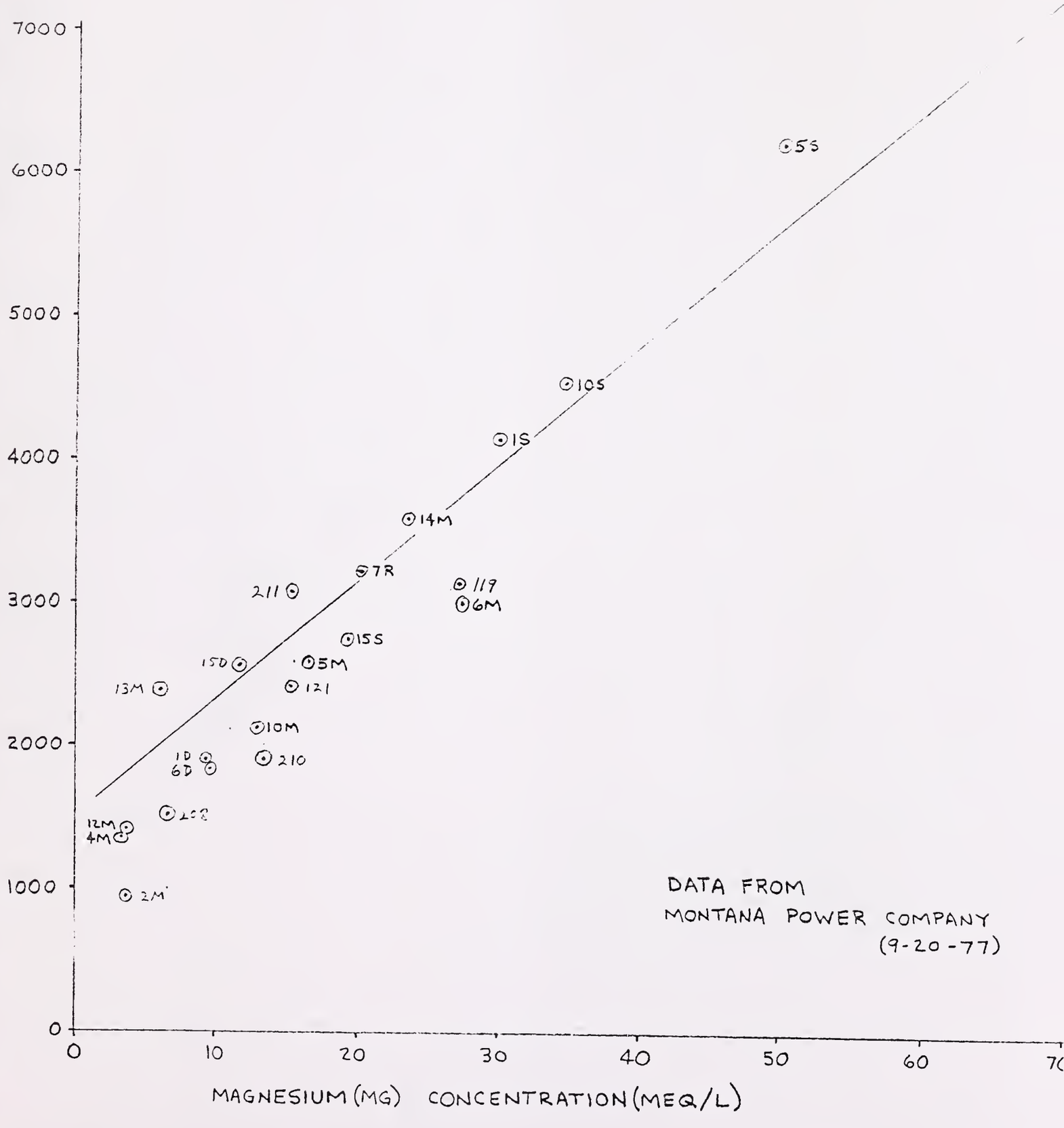
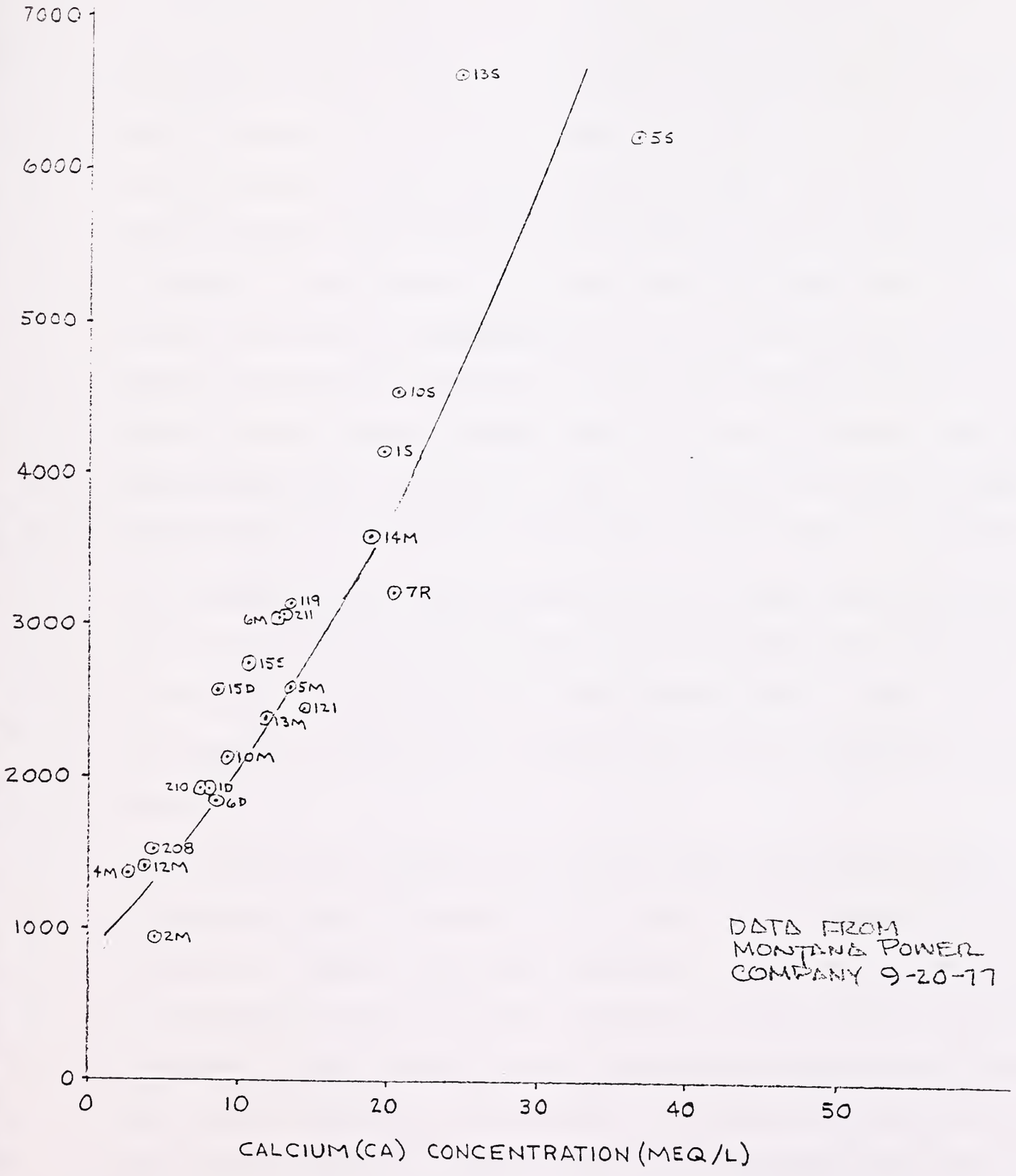


Figure 14.

Specific conductivity in wells versus calcium concentration



Groundwater as sampled by monitoring wells and from data from Van Voast, Hedges, and McDermott (1977) does exceed some criteria for use in irrigation, public water supply, aquatic life, and stockwater. The groundwater is extremely hard, has a high alkalinity and exceeds recommended limits for sulfate and the total dissolved solids for public water supplies of 250 mg/l and 500 mg/l respectively (U.S. Public Health Service, 1962). All wells except 2M exceed 250 mg/l SO_4 and all wells exceed 500 mg/l total dissolved solids (Table 3). Water of this quality is common in eastern Montana and in the Colstrip area and most of the criteria exceeded, are recommended, and not mandatory standards. Water in excess of recommended standards for sulfate and dissolved solids is widely used in Montana. Besides sulfate, the other major constituent that exeeds public water supply criteria is nitrate. The maximum allowable nitrate concentration is 10 mg/l as nitrogen which, in a few wells, is exceeded.

The trace elements iron and manganese are nearly always present in groundwater in the Colstrip area in excess of the recommended limit of 0.3 mg/l and 0.05 mg/l, respectively (U.S. Public Health Service, 1962). This is not specific to Colstrip but is common to the Fort Union Formation in eastern Montana.

For irrigation and livestock use there are some trace elements present in concentrations that have been shown to cause adverse impacts under some conditions. Elements that exceed recommended criteria are (criteria shown in parenthesis) cadmium (.01 mg/l), boron (0.75 mg/l), selenium (0.02 mg/l), aluminum (1.0 mg/l), lead (0.1 mg/l), and manganese (0.2 mg/l) for irrigation; and selenium (0.05 mg/l) for livestock. All these elements were found in Colstrip groundwater in concentrations above some recommended criteria by the investigation by Van Voast, Hedges, and McDermott (1977). (Table 4)

Many constitutents in the water in the Colstrip area and near the ponds water exceed concentrations that have been shown to be detrimental to some aquatic life under some conditions. This comparison, however, is of limited value since most effects reported in the literature were on organisms, in water types, and under conditions that do not exist at Colstrip.

Exchange and sorption of ions including metals is a fuction of particle size. Smaller particles generally have greater surface area and higher cation exchange capabilities. Since the pond system is underlain by silts, fine sands, and clays, it is expected that there would be a high ion exchange capacity in these soils. Cation exchange properties of soils have been studied in ground disposal of many types of wastes, and soils have been found to be an effective media for absorption of trace metals. In monitoring wells 13S, 1S, and 5S, which had had quality changes that may reflect some pond seepage, the concentration of metals in these well waters is substantially lower than in the waste ponds. The cause of this is not certain, however, it may be related to exchange of metals in the porous media as the water moved from the ponds to the wells. As cations are exchanged the exchange sites may become saturated. There is probably a high exchange capacity in strata underlying the ponds and with low pond seepage rates, the exchange mechanism probably will be effective in sorbing cations.

IMPACTS OF POND LEAKAGE

Water level and water quality show a number of relationships between monitoring wells and ponds. Existing data cannot be used to determine exact rates of seepage, however, minor pond leakage was expected and several monitoring wells have had changes in quality that suggest some seepage may be occurring.

The McKay aquifer appears to be unaffected by pond seepage since there have been no significant changes in water quality or water levels. Also, the piezometric contour map (Plate 1) and electrical conductivity relationships in the aquifer show no evidence of impacts. Hydraulic data shows the McKay aquifer generally has a poor hydraulic connection with overlying strata and is reacting slowly or not at all to seepage from the waste ponds.

In the shallow aquifer (McKay overburden), well 5S has continually increased in conductivity and its quality may reflect some seepage from the flyash ponds. Water levels have not risen excessively, thus a small quantity of water may be seeping into this well, but not in sufficient volumes to significantly raise water levels. Similarly, well 1S may be reflecting a small seepage from the flyash ponds as indicated by its conductivity and chemical quality. Well 13S reached a constant but high conductivity and an abnormally high pH and may be indicating some seepage from the bottom ash pond. A leak in a waste line near well 13S was reported (C.Grimm, Montana Power Company, pers. comm., Feb., 1978);thus, the cause of the impact of well 13S is uncertain. Well 10S has a constantly high conductivity and could be affected by some seepage.

A quantitative determination of seepage from ponds near the power plant is difficult to make since no pre-pond data were obtained from the wells. Based on aquifer capabilities for transporting water (see section on Groundwater Movement), an outflow of 5 to a maximum of 15 gpm(gallons per minute) could be seeping from the ponds and creating the poor water quality in the McKay overburden. Water levels in 3 of the 4 poor quality wells (1S, 5S, 10S, !3S) remained constant or declined with only well 10S showing a water level rise. It would seem that any significant leakage would have raised water levels in addition to altering water quality. The present overall impact of these ponds, therefore, appears to be limited to <u>possible</u> seepage of small quantities of wastewater into the McKay overburden.

At the flyash evaporation pond neither the seepage rate or the quality of water in the pond has been accurately determined. This pond was just beginning to be used for ash storage at the end of this project and no impacts were observed.

The potential future impacts of these wastewater ponds on water resources are of considerable interest. The ultimate fate of water that may leak from ponds near the power plants into the McKay overburden or the McKay coal seam would be to flow westward into the East Fork of Armells Creek or to flow eastward toward Rosebud Creek.

The potential rate of groundwater flow in these aquifers is slow and is limited by their low transmissibilities. In addition, water quality in the East Fork of Armells Creek is poor and average flows in this stream are large compared to the potential rate of groundwater inflow. Thus, pond seepage probably will not be detectable in the East Fork of Armells

Creek. Rosebud Creek is about 10 miles from the Colstrip ponds and geological and hydrological conditions between Colstrip and Rosebud Creek are incompletely known. The Rosebud coal and Rosebud coal underburden do not extend to Rosebud Creek (Westinghouse, 1973) and the areal continuity of the McKay is not well known. In view of the relatively incomplete knowledge of hydrogeological conditions toward Rosebud Creek, quantitative impacts of pond seepage on Rosebud Creek cannot be predicted. The large distances, low permeability of the McKay coal and McKay overburden and low permeability of waste pond linings make any waste pond impact on Rosebud Creek improbable.

In the flyash evaporation pond area, the predicted seepage rate is 13 gpm (Bechtel, 1975). The basic pH of this pond water and low permeability of underlying aquifers will probably restrict changes in groundwater quality near the ponds. When pond seepage reaches the East Fork of Armells Creek no measureable impacts are expected due to the stream's poor quality and high flow relative to expected groundwater seepage.

Impact Mitigation

If substantial seepage occurs from the waste disposal ponds at Colstrip, there are techniques available to eliminate or mitigate the impacts. This presumes that water quality associated with the seepage was unacceptable in the aquifer or at points of aquifer discharge. Elimination or abatement techniques include:

(1) Interception of all or part of the seepage water and treatment or impoundment of this water.

(2) Reduction of seepage rates from the ponds.

(3) Construction of new ponds with the required seepage characteristics or in areas not sensitive to seepage.

(4) Eliminate waste water to the pond or alter distribution of waste water to change the quality of seepage water.

Of the listed potential measures, the first and second have the most potential for success with minimum environmental disturbance and cost. Reduction of seepage could occur by sedimentation in the ponds. Nearly all waste ponds tend to have reduced infiltration rates as the ponds age and sediment accumulates on pond sides and bottoms. Flyash is fine-grained and an accumulation would inhibit seepage. Similarly, the other waste ponds would tend to seal themselves with time. The sediment removal in the plant flyash pond could be altered to allow a greater sediment accumulation, thus reducing seepage.

Interception of seeped water by a perimeter well system also would be a possible control technique. Based on aquifer hydraulic characteristics, wells could be designed and installed to stop groundwater migration in the aquifer. Low transmissibilities and small volumes of groundwater in underlying aquifers are suitable conditions for an interception system.

Intercepted water could be returned to the ponds. Based on the calculated rate of water movement of 0.5 in the McKay coal seam and 1.5 feet per day, in the McKay overburden, there would be ample time to establish an interception system to intercept migrating waste waters. A well interception technique appears to be relatively simple, positive, economical and easily implementable.

A long-term groundwater quality monitoring program also should be implemented for the Colstrip ponds. Such a program would show any signficant pond leakage and would allow sufficient time for remedial measures to prevent water quality problems in streams and, if desired, in aquifers adjacent to the ponds. In view of the slow movement of groundwater it is recommended that the waste-ponds and monitoring wells be sampled two to four times annually and water levels be measured monthly. Chemical parameters to be measured should include major ions (Ca, Mg, Na, CO_3-HCO_2, Cl, SO_4), some physical parameters such as pH, specific conductivity, and the following minor elements - nitrate, boron, fluoride, iron, manganese, cadmium, selenium, lead and zinc.

Monitoring results should be interpreted as received to determine aquifer response and adequacy of the program.

BIOASSAY TESTS

To obtain some measure of the possible toxicity of pond waste waters to aquatic organisms several static bioassay tests were run using Daphnia and Fathead minnows. These tests were conducted by the Fisheries Bioassay Laboratory at Montana State University. The fish were tested with one fish per two liters of solution and tests lasted one to two months. Other test conditions and results are described by Dr. Thurston (letter to D. Klarich, Water Quality Bureau, dated April 5, 1978).

> "Fish were not fed during the tests, and under that condition, any results beyond 3-4 weeks begin to be weighted by the lack of nourishment for the test animals. Test dilution water was dechlorinated Bozeman City water.
>
> No one test is conclusive with regard to exact lethal concentration information, but within the limits described above certain trends were observed for the samples tested, under the conditions specified.
>
> Fly Ash Pond. It would appear that close to 100% mortality will occur at 50% concentration in one month, but that at concentrations of 10% and 20% the majority of fish can survive a month. Estimated 96-hr LC50: 25% concentration for the samples tested.
>
> Fly Ash Evaporation Pond. In a single test, 3 out of 7 fish survived for a month at 50% concentration. Estimated 96-hr LC50: No significant mortalities at 100% concentration for the sample tested.
>
> Cooling Tower Blowdown Pond. Although there were a few anamalous mortalities (no trend) at some dilutions, all fish survived at 100% concentration for periods of a month. Estimated 96-hr LC50: No significant mortalities at 100% concentration for the samples tested.
>
> Bottom Ash Storage Pond. Approximately 50% of the fish survived at 50% concentration for a month. Estimated 96-hr LC50: No significant mortalities at 100% concentration for the samples tested."

All test results are in Appendix IV.

TECHNOLOGY TRANSFER

Colstrip power Units 1 and 2 are the first large coal-fired electrical generating power plants using a closed-loop waste system in the Northern Great Plains. This investigation of chemical characteristics of waste waters and containment technology may be of value in future studies of plants and pond systems associated with coal conversion processes. Detailed results of this investigation are described in this report. This section contains a number of considerations and techniques that were proven to be effective in this investigation and also indicates some problems to be avoided. As in all technical investigations, some unanticipated problems occurred and hindsite suggests some study design modifications that would be useful for a more cost-effective investigation.

The following specific items are of importance when considering an investigation similar to this one:

(1) Each aquifer that may be affected should be considered separately and the monitoring system should provide sufficient wells and well spacing to determine groundwater gradients. This requires one set of wells near the ponds and another set some distance away.

(2) Well locations and construction techniques are important. Over-reaming, gravel packing, and cement grouting for completion in a specific aquifer worked well to insure reception of water only from the target aquifer. Paired wells, or cluster wells give good information on effectiveness of hydraulic seals and interaquifer connections. Completion technique involving flushing with fresh water created problems in interpretation of water quality data and should be avoided if possible. Completion should be by techniques that do not involve introduction of foreign water into the system. Development of the wells should continue until very little

sediment is produced in the wells.

An understanding of areal geology and hydrogeology is important in location of monitoring wells to insure proper placement to measure factors such as aquifer recharge and discharge. The wells also should be located where there will be no disturbance of the wells and they will be protected. Coordination with mine and plant planning personnel to insure locations that will be permanent throughout the study is valuable.

(3) Time periods necessary to properly study pond impacts include a minimum of one year of water level and water quality data before waste ponds are used. This will show seasonal trends within the aquifer. The study should then extend at least one full year after filling of the ponds and should include adequate report preparation time. In low permeability aquifers and for low rates of pond leakage, impacts on wells may not be seen for one or more years.

(4) Water level measurements should be taken monthly on each well with a steel tape accurate to 0.01 feet with a clearly established reference point for depth measurements. Selected wells or a well in each aquifer should be monitored continuously with a water level recorder. Piezometric contour maps should be drawn early in the project to determine if there are surveying or water level measurement errors. Piezometric maps commonly will show inconsistencies in the water level data base. Barometric efficiencies should be measured to distinguish water table changes due to atmospheric pressure variations.

(5) Short duration aquifer tests (15 minutes) gave good approximations of aquifer hydraulic characteristics, however, longer-term tests extending from four to twenty-four hours give a more reliable measure of aquifer

properties. Accurate storage coefficients are difficult to obtain from pumped wells unless there are one or more nearby properly located observation wells.

(6) Water quality in waste pond systems is a function of the process and quality of natural water input to the process. Ash/water reactions are a dominant factor and exert a profound influence on overall water quality. The plant mode of operation is important in that waste waters from various sources can be mixed causing variations in pond quality.

(7) Water quality sampling should proceed from a relatively simple screening process including a few selective parameters, to a more comprehensive analysis. It should be demonstrated that water quality represents formation water before numerous parameters are measured in each monitoring well. Sampling should be preceded by pumping or by bailing a minimum of three times the volume of water in the hole. Water quality in stagnant wells will (for some reason that is unclear) be different from water quality in the aquifer. Commonly, samples collected from wells with small hand bailers that do not cause significant movement of aquifer water to the well will not accurately represent formation water. As water quality data are collected and are shown to be relatively consistent, the complexity of analysis should increase. As the water system is understood, the frequency of monitoring can be decreased. Sampling frequency must be related to expected water movement rate and may vary from monthly during early phases of the study to yearly during long-term monitoring.

(8) Any water level or water quality monitoring program should be established

for a long-duration, that is, a minimum of five years. Water quality and water level impacts may be slow to show themselves in aquifer systems and a consistent water level and chemical data base must be collected to insure recognition and delineation of impacts.

REFERENCES

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APPENDIX IV

BIOASSAY RESULTS ON COLSTRIP WATER SAMPLES

March 28, 1978

BIOASSAY RESULTS ON COLSTRIP WATER SAMPLES COLLECTED 3/10/77, 5/17/77, 7/12/77, AND 10/6/77; RECEIVED FROM MONTANA WATER QUALITY BUREAU

Tests were conducted using fathead minnows (Pimephales promelas) as the test animal, 5 fish per 10 liters total solution (unless otherwise specified). Concentration values given below are in terms of percent dilution (i.e., percent sample of total solution).

FLY ASH POND

1. 3/10/77 Samples, 27-day bioassay.

There was total mortality at 100% concentration (pH 8.12) in 6 days, at 75% (pH 6.40) in 10 days, and at 50% (pH 5.74) in 27 days. D.O. 4.36-5.71 mg/ℓ, Temp. 20.5-20.7 C.

2. 5/17/77 Samples, 48-day bioassay.

There was total mortality at 50% concentration (pH 7.57) in 28 days, and at 40% (pH 7.80) in 45 days. Other mortalities were: 2 at 30% (pH 7.96) in 48 days, 2 at 20% (pH 8.08) in 48 days, 4 at 10% (pH 8.15) in 48 days. D.O, 7.30-7.40 mg/ℓ, Temp. 21.1-21.3 C.

3. 7/12/77 Samples, 33-day bioassay.

There was total mortality at 50% concentration (pH 7.53) in 22 days, at 40% (pH 7.59) in 32 days, and at 30% (pH 7.81) in 32 days. There were 2 mortalities at 20% (pH 7.99) in 33 days. D.O. 6.95-7.11 mg/ℓ, Temp. 21.5-21.6 C.

4. 10/6/77 Samples, 32-day bioassay.

Note: 7 fish per 15 liters total solution.

There were 4 mortalities at 50% concentration (pH 7.83) in 32 days, 2 at 40% (pH 8.01) in 32 days, 0 at 30% (pH 8.10) in 32 days, 1 at 20% (pH 8.18) in 32 days. D.O. 7.47-7.49 mg/ℓ, Temp. 19.0-19.1 C.

FLY ASH EVAPORATION POND

1. 10/6/77 Samples, 32-day bioassay.

Note: 7 fish per 15 liters solution.

There was total mortality at 100% concentration (pH 7.95) in 19 days, and at 75% (pH 8.06) in 28 days. There were 4 mortalities at 50% (pH 8.17) in 32 days. D.O. 7.59-7.65 mg/ℓ, Temp. 18.8-19.3 C.

COOLING TOWER BLOWDOWN POND

1. 3/10/77 Samples, 64-day bioassay.

There was 1 mortality at 100% concentration (pH 8.11) in 64 days, 2 at 75% (pH 8.12) in 64 days, 4 at 50% (pH 8.07) in 64 days. D.O. 6.01-6.11 mg/ℓ, Temp. 20.5-20.6 C.

2. 5/17/77 Samples, 48-day bioassay.

Note: 4 fish per 7 liters of solution.

There were no mortalities at 100% concentration (pH 8.19) in 48 days, 3 at 75% (pH 8.12) in 48 days, 2 at 50% (pH 8.14) in 48 days, 1 at 25% (pH 8.27) in 48 days. D.O. 7.20-7.50 mg/ℓ, Temp. 21.0 C.

3. 7/12/77 Samples, 33-day bioassay.

There were no mortalities at any test concentrations in 33 days. pH 8.30-8.35, D.O. 6.98-7.03 mg/ℓ, Temp. 21.6-21.7 C.

4. 10/6/77 Samples, 32-day bioassay.

Note: 7 fish per 15 liters solution.

There were no mortalities at any test concentrations in 32 days. pH 8.35-8.38, D.O. 7.38-7.45, Temp. 18.9-19.1 C.

BOTTOM ASH STORAGE POND

1. 3/10/77 Samples, 64-day bioassay.

There was total mortality at 100% concentration (pH 8.07) in 53 days and at 75% (pH 8.08) in 54 days. There were 4 mortalities at 50% (pH 8.06) in 64 days. D.O. 5.46-6.01 mg/ℓ, Temp. 20.3-20.4 C.

2. 7/12/77 Samples, 33-day bioassay.

There were 4 mortalities at 100% concentration (pH 8.31) in 33 days, 1 at 75% (pH 8.22) in 33 days, 1 at 50% (pH 8.27) in 33 days. D.O. 6.60-6.92 mg/ℓ, Temp. 21.6-21.7 C.

Robert V. Thurston, Director

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FISHERIES BIOASSAY LABORATORY

MONTANA STATE UNIVERSITY, BOZEMAN 59715

21 February 1977

BIOASSAY RESULTS ON COLSTRIP WATER SAMPLES RECEIVED 1/13/77 FROM MAX BOTZ, MONTANA WATER QUALITY BUREAU.

Tests were run using *Daphnia pulicaria* as the test animal, 5 animals per 200 ml total solution. Values expressed below are in terms of percent sample of total solution (ml sample/200 ml total solution x 100).

These are screening bioassays, and although the results could be reported as a statistical LC50 with wide confidence limits using our statistical method (Hamilton et al. The trimmed Spearman-Karber method for estimating median lethal concentrations in toxicity bioassays. Environ. Sci. Technol. 11, In press.), I chose not to do so, but rather to report these findings in a narrative form. I believe it presents a clearer picture of the case and more graphically illustrates the wide variability of results among various dilutions. In each case, however, I have provided an approximate LC50 for discussion purposes.

Bottom Ash - Clearwater Pond [Approximate 96hr LC50: 75%]

In a screening bioassay there were no mortalities at 50% concentration, and total mortality at 100% concentration. pH range 8.0-8.3, temp 21C. In a second bioassay at 10% gradations between 50-100% concentration, mortalities were as follows: 1 at 50%, 1 at 60%, 3 at 70%, 3 at 80%, 4 at 90%, 5 at 100%. pH range 7.6-7.7, temp 23C.

Fly Ash - Clearwater Pond [Approximate 96hr LC50: 15%]

In a screening bioassay there were no mortalities at 10% concentration, and total mortality at 50% concentration. pH 6.0-7.7, temp 21C. In a second bioassay at 5% gradations between 10-30%, there were no mortalities at 10% concentration, 4 at 15%, and 5 at 20, 25, & 30%. pH range 7.2-8.0, temp 23C.

Cooling Tower Blowdown Pond [Approximate 96hr LC50: 75%]

In a screening bioassay there was 1 mortality at 25%, 3 at 50%, and 4 at 100%. pH 8.0, temp 21C. In a second bioassay there were 0 mortalities at 25%, 1 at 50%, 3 at 75%, and 5 at 100%. pH 8.0-8.2, temp 23C.

Armelles Creek Below Town Flume B

In a bioassay at 10%, 25%, 50%, and 100% concentrations, there were no significant mortalities. pH range 8.0-8.4, temp 21C.

R.V. Thurston

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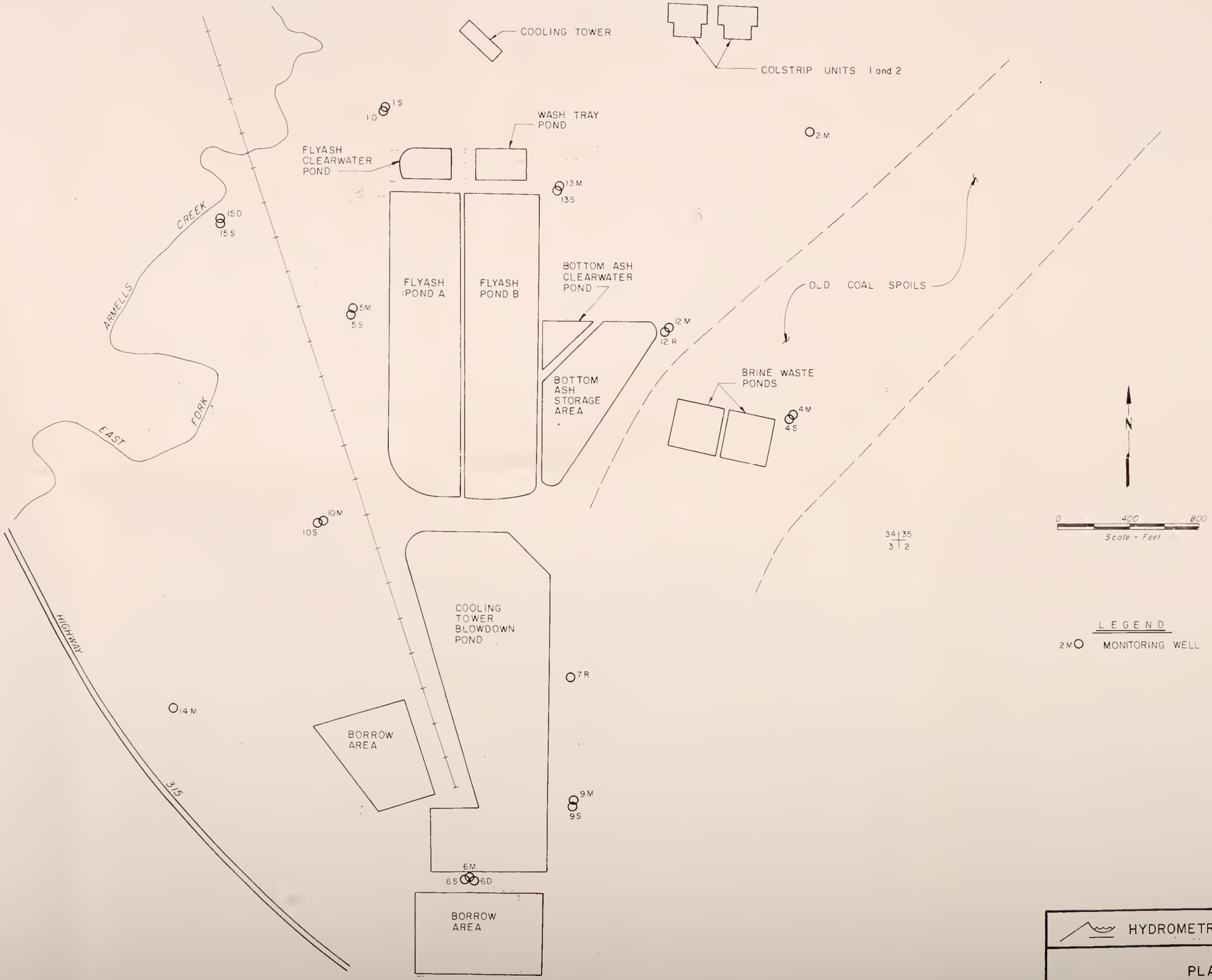
TABLE 3A SELECTED WATER QUALITY STATISTICS FOR PONDS IN THE COAL ASH AREA

POND	Specific* Conductance umhos/cm	SO_4 mg/l	pH units	Zinc, Total Rec. mg/l
FLYASH POND SYSTEM				
Number of samples	13	8	7	6
Maximum	10,053	9400	7.3	.32
Minimum	3,493	5150	4.6	.15
Mean	7,282	7,230	5.8	.25
WASH TRAY				
Number	5	3	3	4
Max	9600	8958	4.20	.45
Min	6616	5640	3.93	.34
Mean	8068	7696	4.08	.416
BOTTOM ASH CLEAR RETURN				
Number	7	4	5	5
Max	5627	2900	9.90	.01
Min	3701	1707	8.60	<.01
Mean	4334	2572	9.24	<.01
COOLING TOWER BLOWDOWN				
Number	11	9	8	8
Max	4671	2760	9.10	.56
Min	3193	1750	7.77	<.01
Mean	4065	2314	8.36	.18
FLYASH EVAPORATION				
Number	4	3	2	2
Max	9319	8333	8.50	.02
Min	8551	7860	8.20	.01
Mean	9022	8118	8.35	.02
FISHING POND				
Number	1	1	1	1
Max	4464	2850	7.96	<.01
Min	4464	2850	7.96	<.01
Mean	—	—	—	—

* Four of the 13 samples represent pond water quality during early transient state flow operations. By eliminating those 4 values, the mean conductivity is 8773 umhos/cm, with a minimum equal to 7109 umhos/cm. The maximum value remains 10,053 umhos/cm.



HYDROMETRICS
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PLATE I

PLAN MAP SHOWING EFFLUENT DISPOSAL PONDS AND MONITORING WELLS NEAR COLSTRIP, MONTANA